RESEARCH REPORT

WALL MOISTURE PROBLEMS IN ALBERTA DWELLINGS

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100-07498/

WALL MOISTURE PROBLEMS IN ALBERTA DWELLINGS

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Alberta Housing Industry
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FOREWORD

The study documented in this report was sponsored jointly by Canada Mortgage and Housing Corporation (CMHC) and the Alberta Housing Industry Technical Committee (AHITC).

One of the ways CMHC contributes to the improvement of housing and living conditions in Canada is by communicating the results of its research. This report is one example of this effort Contact CMHC for a list of available information products on a variety of social, economic, environmental and technical housing-related topics.

AHITC is a strategic alliance of the major organizations representing Alberta's residential construction industry, including representatives of provincial and local builder associations in Alberta, the Alberta New Home Warranty Program, the cities of Calgary and Edmonton, CMHC, and Technical and Safety Services, Alberta Municipal Affairs. AHITC identifies, investigates and facilitates the development of practical and effective solutions to technical problems in the residential construction industry in Alberta.

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ACKNOWLEDGEMENTS

Canada Mortgage and Housing Corporation as the main funder for this study thanks the Alberta Housing Industry Technical Committee (AHITC) for their partnership contibutions in this project. In addition to the AHITC financial support, CMHC also acknowledges Linden Holmen's coordination work between CMHC, the AHITC committee members, and the consultant.

The Alberta Housing Industry Technical Committee acknowledges the following financial contributors that made it possible to provide AHITC funding for this project.

- Industrial Research Assistance Program (IRAP) of the National Research Council of Canada,
- The Alberta Home Builders' Association
- The Alberta New Home Warranty Program
- Reemay Corporation,
- Imasco Minerals Inc.

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RÉSUMÉ

Les problèmes d'humidité des murs des bâtiments accusent moins d'intensité en Alberta qu'en région côtière de la Colombie-Britannique (C.-B.), même si leur fréquence dans l'ensemble n'est pas acceptable à longue échéance. Les propriétaires ne s'attendent pas, et on ne devrait pas s'attendre à ce qu'ils doivent le faire, à devoir tolérer des cas d'infiltration d'eau à l'intérieur de leur maison, qu'elle soit neuve ou bien entretenue, sauf par temps exceptionnel. À l'heure actuelle, on estime qu'environ 5 % des maisons neuves subissent des infiltrations d'eau annuelles ou plus fréquentes, et qu'une proportion équivalente d'habitations subit des infiltrations d'eau, qui ne se rendent toutefois pas jusqu'à l'aire habitable.

On pourrait prévenir les problèmes d'infiltration d'eau les plus répandus en apportant de simples améliorations lors de la construction, Cependant, ces problèmes sont plus difficiles à corriger après l'achèvement des travaux de construction.

La plupart des problèmes surviennent aux points de pénétration par le bardage surtout au pourtour des portes et des fenêtres, aux points de raccordement des terrasses et des balcons, et, en dernier lieu, aux points de pénétration de petite taille. Apporter de légères améliorations peu coûteuses au mode de raccordement de la membrane secondaire de protection contre les intempéries et des solins vis-à-vis les ouvertures, améliorer les fenêtres et les solins, et revoir les détails d'exécution au pourtour des terrasses permettraient d'éliminer la plupart des problèmes.

Il arrive souvent que les cadres de portes et de fenêtres n'offrent pas de projection suffisante ou ne comportent pas de larmier. Les fabricants devraient produire des fenêtres qui s'ajustent efficacement à la membrane de revêtement et au parement, sans devoir recourir à des alternatifs tel que des solins de membrane autocollants et prolongation de la pièce d'appui pour créer un larmier efficace. De nombreuses fenêtres de vinyle sont trop flexibles, et leurs mouvements thermiques importants ne sont pas pris en considération lors de la conception des détails de construction.

Les détails d'exécution au pourtour des terrasses, qui permettent d'installer les membranes en place en dernier, doivent faire l'objet d'améliorations destinées à évacuer efficacement l'eau vers l'extérieur.

D'après l'observation des bâtiments à l'étude et l'expérience des investigateurs, la qualité du stucco satisfait rarement aux exigences minimales de l'Alberta Building Code (ABC). La qualité du stucco et sa mise en oeuvre devront donc être améliorées.

Les problèmes observés au-dessus des fenêtres et des portes étaient souvent plus importants dans le cas des étages les plus éloignés des débords de toit, et moins de problèmes se produisaient dans le cas des murs protégés ou opposés aux vents dominants. Cette situation indique qu'il faut porter un soin particulier aux endroits exposés et que le coût pour éviter les problèmes peut être atténué en n'ayant pas recours à une seule solution généralisée pour tous les bâtiments et toutes

les parties d'un bâtiment. Les pratiques courantes sont souvent acceptables pour les endroits non exposés à des conditions rigoureuses et protégés par des débords, mais elles ne suffisent pas pour les endroits exposés. Le recours à des murs aménagés avec une cavité d'évacuation de l'eau et à des solins de membrane autocollants constitue sans doute le traitement minimal efficace à réserver aux parties exposées des bâtiments en milieu non protégé.

Les taux de fuites d'air de la plupart des bâtiments sont assez élevés que si les occupants veulent maintenir un degré élévé d'humidité à l'intérieur en hiver, de graves problèmes d'humidité liés à la condensation risquent de survenir. Il est recommandé d'assurer l'étanchéité à l'air du revêtement intérieur en plaques de plâtre. Par contre, il n'est pas recommandé de recourir à un pare-air extérieur. Les détails et pratiques courrantes pour créer un pare-air intérieur--particulièrement au pourtour des portes et fenêtres--doivent être améliorés.

Les correctifs suivants devraient réduire considérablement les infiltrations d'eau, sans créer d'autres problèmes de condensation.

- Rendez les revêtements intérieurs de finition plus étanches à l'air que le parement extérieur, surtout au pourtour des fenêtres, à la fois pour y réduire les fuites d'air et neutraliser l'action du vent sur les surfaces extérieurs humides.

- Chevaucher le papier de construction (pour favoriser l'écoulement de l'eau par gravité, posez-le avec un chevauchemnt de 100 mm), en particulier au seuil des ouvertures et au-dessus des solins métalliques. Servez-vous d'un matériau et d'une technique d'étanchéité de qualité élevée au pourtour des portes et des fenêtres. Sauf au pourtour des ouvertures, le papier de construction standard suffit à condition d'être bien posé. L'emploi d'un papier offrant une meilleure résistance à l'eau (donc une meilleure résistance à la vapeur d'eau) sur toute la surface des murs pourrait accroître les problèmes de condensation en hiver. Ne faites pas usage de ruban adhésif avec le papier imprégné d'asphalte et ne comptez pas sur le ruban pour assurer une étanchéité durable.

- Utilisez deux couches de papier de construction derrière le stucco, de préférence en décalant les joints verticaux et les attaches, surtout si le papier est exposé pendant une longue période.

- Préparez le stucco et appliquez-le en respectant les exigences minimales de l'ABC, en n'utilisant que les ingrédients énoncés dans le code. Évitez de recourir à des additifs qui permettent de réaliser des économies de main-d'oeuvre, notamment le savon, l'excès d'entraîneurs d'air et l'argile, puisqu'ils pourraient exercer des effets défavorables sur les propriétés du produit fini.

- Posez les garnitures et les accessoires pour le bardage de vinyle ou de métal de façon à améliorer les avantages inhérents de l'écran pare-pluie du bardage.

- Utilisez des solins métalliques avec larmiers efficaces aux bords inférieurs du parement, aux joints horizontaux du parement, aux surfaces de stucco en saillie, en partie supérieure des murs en stucco et des protections, et au-dessus des points de pénétration.

- Employez des fenêtres conçues en fonction des principes de l'écran pare-pluie.

- Prévoyez des larmiers sur les pièces d'appui des fenêtres, en assurant une projection suffisante de façon à tenir compte de l'épaisseur du parement sans compromettre l'efficacité du larmier.

- Servez-vous de solins métalliques assurant une protection supérieure à celle qui est présentement considérée comme standard, comportant des larmiers efficaces, une pente suffisante, une prolongation au délà des montants de la fenêtre et avec talons pour dévier l'eau vers l'extérieur au bout du solin.

- Tenez compte de l'exposition au moment d'adopter des mesures de protection. Ayez recours à un mur avec écran pare-pluie, en comptant sur des matériaux et une exécution de qualité élevée pour les endroits fortement exposés.

EXECUTIVE SUMMARY

Wall moisture problems are less severe in Alberta than in coastal British Columbia (B.C.), however the frequency of overall problems is not acceptable in the long term. Owners do not, and should not, be expected to tolerate incidents of water entering the interiors of new or well-maintained homes unless weather conditions are extreme. Currently, it is estimated that approximately 5% of new homes experience leakage to the interior under conditions that occur on an annual or more frequent basis, and an equal proportion may experience leakage into the structure but not the interior living space.

The most common types of leakage could be avoided by relatively simple improvements in initial construction, but they are not so simple to repair after construction is completed.

Most problems occur at penetrations through the cladding: window and door perimeters in particular, followed by deck and balcony connections, and lastly by smaller penetrations. Minor and inexpensive improvements in the way the secondary weather barrier is connected to flashings at openings, improvements in windows and flashings, and revised deck perimeter details would eliminate most problems.

Window and door frames often do not have adequate projection or drips. Window manufacturers should make windows that interface effectively with properly applied sheathing membrane and cladding, without expensive alternatives like peel-and-stick membrane flashings, and without a need to augment the sills to provide effective drips. Many vinyl windows are too flexible and experience significant thermal movements, which are not considered in the design.

The details used at perimeters of decks, which have evolved to permit the deck to be installed last, need to be improved so that they provide adequate drainage to the exterior.

Based both on observation of the buildings in the study, and on the prior experience of the investigators, the quality of stucco is rarely up to the minimum standard set by the Alberta Building Code (ABC). The quality of the stucco and application should be improved.

Observed problems at heads of windows and doors were most often more significant at floors furthest from the eave, and all problems were less common on walls that were sheltered, or that faced away from the predominant winds. This suggests that special care should be taken in exposed locations, and that the cost of avoiding problems can be minimized by not employing a one-size-fits-all approach for all buildings and all parts of a building. Current practices are often acceptable for locations not exposed to severe conditions and sheltered under overhangs, however they are inadequate in more exposed locations. Walls with drained cavities and peel-and-stick membrane flashings are potentially the minimum effective treatment

for exposed portions of buildings on exposed sites.

Air leakage rates in most buildings are significant enough that if higher levels of indoor humidity in winter are demanded by occupants, serious moisture problems from condensation can be anticipated. Air sealing at the interior plane of the gypsum board is recommended. The use of an exterior air barrier is not recommended. Current interior air barrier details, especially at windows and doors need to be improved.

Use of the following specific remedies should significantly reduce the incidence of moisture leakage, without creating new problems with condensation:

- Make interior finishes more airtight than the cladding, particularly at window perimeters, both to reduce air leakage and to neutralize the effect of wind acting on wet exterior surfaces.

- Lap building paper properly (to shed water by gravity, with 100 mm overlaps), particularly at sills of openings and over metal flashings. A higher quality material and method of sealing are required at perimeters of window and door openings. Except around openings, standard building paper is adequate if properly installed. Use of paper with more water resistance (and hence more vapour resistance) for entire walls might increase problems with winter condensation. Do not use adhesive tape with asphalt impregnated paper, and do not rely upon the tape for a durable seal.

- Use two layers of building paper under stucco, preferably with laps and fasteners offset, particularly if the paper is exposed for an extended period of time.

- Mix and apply stucco to meet the minimum requirements of the ABC, using only the ingredients listed in the code. Omit labour saving additives that might have adverse effects on properties of the finished product, like soap, excess entrained air, and clay.

- Install trim and accessories for vinyl and metal siding so as to enhance the inherent rainscreen advantages of the siding.

- Provide metal flashings with effective drip edges for bottom edges of cladding, horizontal joints in cladding, projections from stucco surfaces, tops of stucco walls and guards, and heads of penetrations.

- Use windows designed based on rainscreen principles.

- Provide drips at sills of windows, with enough projection from flange to face of casing to accommodate the thickness of cladding and still allow the drip to be effective.

- Use metal flashings with more projection than is now standard, and with effective drip edges, adequate slope, extended beyond the jambs, and with end dams.

- Take exposure into account when selecting protective measures. Use a rainscreen wall assembly with high quality materials and workmanship for severe exposures.

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1.0 INTRODUCTION

1.1 BACKGROUND

Water penetration problems in residential low rise wood frame buildings were documented for Canada Mortgage and Housing Corporation (CMHC) in the "Survey of Building Envelope Failures in the Coastal Climate of British Columbia", completed in 1996. This report clearly indicated that there was a significant problem with water leakage through residential walls and windows in the coastal region of British Columbia (B.C.). Exterior water was determined to be the predominant moisture source, not construction moisture or interior sources. Interface details were the primary source of moisture ingress, including window perimeters, windows, decks, balconies, and saddle connections. Lack of details, poor quality of details, and poor construction were identified as significant contributors. Problems were experienced with all claddings, however, the number of problems and the cost to repair were higher with stucco.

Although the majority of industry participants do their best to ensure that the parts of the work over which they exert control are successfully completed, the same economic pressures which tend to lead to reduced quality of construction; pay by piecework, lack of accountability of persons responsible for creating problems (who, not being called to account, may be unaware of the problems), pressure to complete work rapidly to meet the demands of a hot market, reliance by enforcement officials on builders and designers (and vice versa), fee shopping by developers, and faith on the part of buyers that someone else is looking after their interests so that they can shop on price and appeal alone, all apply in Alberta as much as in B.C. Confirmation that these factors are at work was beyond the scope of this study, as it was for the B.C. study.

Substantial differences in climate lead one to expect that problems may manifest themselves differently in Alberta. Compared to Vancouver, Calgary and Edmonton's fifteen minute rainfalls are twice as much. One day rainfalls and wind loadings are similar. Calgary has a significantly greater driving rain wind pressure (220 Pa @ 10 m above grade with a one in five year probability) than Edmonton and Vancouver (both 160 Pa @ 10 m above grade with a one in five year probability). However, Alberta has approximately one third of the total annual precipitation of Vancouver, and peak rains occur in summer, rather than winter. In addition, almost all of Vancouver's precipitation is in the form of rain, whereas a significant portion of the total precipitation in Alberta is snow.

In Vancouver, the majority of rainfall occurs during winter months when the drying potential (difference in partial pressure of water vapour at wetted surfaces compared to exterior air) is lowest, resulting in prolonged wetting. Alberta has the majority of its precipitation in summer when the drying potential is greatest, and has fewer periods of consecutive days of rain. This

suggests that similar construction may be less prone to long-term damage from prolonged wetting, despite potentially greater rain penetration, in Alberta than in coastal B.C.

Because winter temperatures are lower in Alberta, a greater potential for condensation damage due to air leakage and diffusion from the interior exists than in coastal B.C., if interior conditions are similar. This may increase the moisture content within the walls during the winter months, adding to moisture due to rain penetration during the summer months.

Two-storey single family and duplex residences are more common, in proportion to the total market, in Alberta than in metropolitan coastal B.C., and Alberta condominiums have up until now involved fewer complicated designs with decks, walkways, sloped glazing, articulated surfaces and complex forms. Otherwise, building shapes, fenestration, overhangs, and detailing have been similar. Complex building forms are becoming more common in Alberta residential construction as time passes.

Rain penetration problems with residential buildings in Alberta were brought to the attention of the Alberta Housing Industry Technical Committee (AHITC) in 1997. Builders, window manufacturers, CMHC, and members of the AHITC formed a working subcommittee to carry out a study of water entry problems in residential building envelopes in Alberta, with the support and guidance of CMHC.

Rain water leakage in Alberta residential buildings is a problem known to the investigators who conducted the study. They had previously been asked by several builders and home owners to evaluate and/or test leaking homes and condominiums, all of which were stucco clad. Despite extensive initial repairs prior to their involvement, the leakage had often continued due to reliance on caulking, generally applied in the wrong locations. Significant sources of leakage were determined at window/wall interfaces, balcony connections, through windows and patio doors, and at flues, vents, and electrical outlets. Wall and window detailing generally relies on face-sealing, which often blocks potential drainage paths. Vertical rises along potential leakage paths are often minimal. Flashing dimensions have been reduced, with current flashings typically having no projection beyond the face of the frame and no drips. Vented and drained screens, when they occur (vinyl siding for instance), are accidental, not deliberate design choices.

Other observations have included significant air leakage through window perimeters and other penetrations. The use of nailing flanges on windows as the sole means of attachment and sealing has contributed to problems with ineffective head flashings and sheathing membrane laps. Details for sealing penetrations such as windows, flues, vents, and electrical fixtures, are often not provided. Drawings typically include plans, elevations, and whole-building sections, assuming that tradespeople know how to construct the details. However, in reality the tradespeople often have limited experience and training as to correct sealing procedures, and

little incentive to improve. Details included in industry standard documents do not always allow for trade coordination, and, to reduce construction time, are often ignored or neglected. There is ample opportunity for water penetration to occur in Alberta through residential walls and windows. The significance, severity, cause and remedy of the problem in Alberta are described in the following sections, based on the data collected and observations made during this study, and the investigators' prior experience.

1.2 ISSUES AND OBJECTIVES

The objective set out for this study was to investigate a representative sample of dwellings with various types of windows and wall claddings, to draw conclusions on the sources and causes of moisture related problems through walls and windows, to make recommendations to remedy the problems, and to recommend changes in construction practices to avoid similar problems in the future. The study also included analysis to correlate water entry problems with design and construction features of building envelopes, and comparison of the nature and causes of moisture problems in Alberta with those previously found in coastal B.C.

1.3 SCOPE

The scope of this study involved the evaluation of moisture penetration from both exterior and interior sources into walls and windows of wood framed single family dwellings and low-rise multiple dwellings (four storeys or less). Buildings examined were predominantly situated in Calgary and Edmonton. To minimize the influence of maintenance and significant changes in construction methods and materials, only buildings of less than 10 years of age were included. The range of cladding reviewed included: stucco, vinyl siding, metal siding and brick. Windows included various materials (wood, PVC and aluminum clad) and types (awning, slider, casement and fixed).

The study was limited to walls and openings in walls, excluding foundation and roof leakage. Due to a greater than normal snowfall occurring in Edmonton during the period of investigation, building occupants often asked for evaluation of current ice damming problems. Review of water leakage through cracks or voids in concrete foundations was also requested. These sources of leakage were beyond the scope of this study to review, and are not reported.

The field investigation was constrained by the need to complete the observation and data collection portion during winter (as required by the CMHC timetable). It was not possible to observe building performance, wetting patterns or water management during rainfalls. Water testing could not be performed due to overnight freezing conditions. Stucco could not be removed or replaced during the investigation period due to freezing conditions, which preclude

repair of stucco, and unwillingness of building owners to have portions of the cladding removed. The supply of sample buildings was limited because few buildings had leaked during the prior seven months (the last major rainstorm). Previous known problems had since been repaired in the majority of instances. The information provided by the participants was tempered by the investigator's judgement and experience, rather than testing on site.

2.0 METHODOLOGY

2.1 VARIATION FROM THE B.C. STUDY

The Alberta study has some significant differences from the B.C. study. Both studies surveyed water penetration through residential wood framed walls and windows. Alberta's study was primarily based on single family and low rise residential dwellings, while the B.C. study included only three and four storey buildings. This is presumably due to condominiums having been predominantly constructed in the B.C. study area, while more single family homes were constructed in Alberta over the past ten years.

The forms, data collection and methodology, were somewhat modified from the B.C. study. The B.C. study involved a much larger number of buildings, requiring several evaluators and a large data base, yet still had difficulty obtaining a sample representative of the population. The Alberta study has involved a smaller number of buildings for specific evaluation, making a representative sampling more difficult. Neither database is of sufficient size to allow for inferential statistical analysis of the buildings reviewed, and neither database is a random sample representative of the population. The B.C. study did not provide recommendations for repair of existing problems nor was the extent of the problem estimated. The B.C. study did not include brick or metal siding, although limited samples of these cladding types were included in the Alberta study.

2.2 CRITERIA FOR SAMPLE BUILDINGS

Sample buildings were selected based on providing an accurate representation of common Alberta single family and low-rise multi-family wood framed construction practice over the past 10 years. Most buildings were from Calgary and Edmonton, although some relevant buildings outside of these areas were included. Claddings, windows, sheathing, sheathing membranes and wall construction methods were restricted to those which have been commonly used. Fifty buildings were included in the study.

Claddings included stucco, brick, vinyl siding and aluminum siding. Windows were PVC or aluminum clad wood frames with perimeter nailing flanges, or wood with brick moldings. Exterior sheathing was oriented strand board (OSB) or untreated exterior grade plywood. No instances of insulated sheathing were observed. Exterior sheathing membranes included asphalt-impregnated Kraft building paper and 60 minute papers, spunbonded polyolefin sheet housewrap, and perforated polyethylene sheet housewrap. Ordinary building paper and spunbonded polyolefin housewrap were by far the most common.

2.3 SAMPLE BUILDINGS

The intent of this study was to have sample buildings provided for investigation through various industry representatives, including builders, regulatory agencies, suppliers and manufacturers who had committed to assist in implementing this study. Few buildings were provided for review. Commonly, buildings which had experienced leakage the previous summer had already been repaired. In addition, many builders were willing to talk generalities and construction practices, but were unwilling to discuss specific buildings. Files were not made available, however, it is assumed that most builders' files would have limited detailed documentation and generally no photographs. Therefore, with the cladding in place, review of the sheathing membrane application procedures and sealing at penetrations was limited.

For these reasons the sample buildings were primarily obtained from previous files, contacts made during the study, and viewing of homes currently under construction.

Three types of buildings were included:

- buildings where a known moisture problem was identified by the occupant or visible from the exterior, including repairs to previous problems,
- buildings where there were no known moisture problems, and
- new buildings with the exterior cladding currently under construction allowing for review of current materials and practices.

Due to the limited cladding which could be removed during the study period, and limited documented buildings made available, buildings with the cladding currently under construction were very beneficial in observing current construction practices. Window installation, sheathing membrane installation, and flashing details were readily visible.

2.4 DATA INPUT FORM

The database and data collection forms created for CMHC by the B.C. study were reviewed and utilized as a template for the Alberta study. The method of collecting information for the study was based on relevant changes to the format of the B.C. study. A copy of the Data Input Form is included in Appendix A, which describes how the forms were utilized and interpreted during input.

2.5 DATABASE

The information obtained from the Data Input Forms was recorded in a modified version of the B.C. study database, using Microsoft Access97. Information from all buildings reviewed was entered. All information was stored based on a generic building identification number.

2.6 DATA COLLECTION

Procedures were implemented to ensure consistency and accuracy of the data collection and entry into the database. All data were recorded on site by the same person to ensure consistent evaluation of similar conditions on different buildings. The data was subsequently reviewed during entry, and again reviewed by query reports to ensure consistency and minimize errors. Photographs of most observations were retained on file to allow for subsequent review.

2.7 BUILDER INTERVIEWS

Several industry representatives were interviewed informally, including Alberta New Home Warranty Program (ANHWP), builders, regulatory agencies, suppliers, manufacturers and home owners. Generally, the following concerns were expressed by most of the representatives.

- Water penetration in residential dwellings in Alberta is a significant problem. Estimates indicated that approximately 5% of homes constructed in the past five years have experienced some form of water penetration through the walls and windows. Estimates varied significantly between builders, generally from zero to 10%. ANHWP - Edmonton indicated that in recent years approximately 23% of their claims have been water penetration related (although this figure includes subgrade water penetration). Of the conciliation claims, approximately 40% were related to wall penetrations including windows and perimeters, 13% due to stucco and 4% related to vinyl siding (figures which may represent a market share, rather than a relative problem incidence).

- Problems were most pronounced in the past five years. This coincides somewhat with significantly increased use of the following: window perimeter nailing flanges, vinyl (PVC) windows, housewraps, housewrap tapes, and an increased volume in construction.

- Many builders have seen a reduction in moisture related problems in the last year due to revisions in their installation procedures, training and quality control. Others are still attempting to resolve the problem.

- A higher incidence of problems was reported with stucco as compared to vinyl siding. Problem buildings with vinyl cladding may have been under-represented because leakage through vinyl siding is often readily repaired by removal and replacement of a few sections of siding at minimal cost (often by the siding applicator), making problems with vinyl clad buildings less memorable. Repair of stucco moisture problems often requires the removal and replacement of stucco which is more difficult and costly.

- Costs of repair varied substantially from a few hundred dollars to tens of thousands of dollars. Replacement of deteriorated framing or sheathing was not required, a very marked difference between the Alberta and B.C. results.

- Problems were most often related to workmanship: inadequate installation of flashings or lapping of the sheathing membrane at penetrations through the wall.

- Leakage through deck junctions and foundation rim joists was experienced by some builders.

- Few problems were experienced due to leakage through other penetrations; fireplace vents, electrical outlets, hose bibs, gas lines, dryer vents, etc. The majority of these penetrations are generally installed in sheltered locations.

- Water penetration was rarely related to leakage through the window frame itself, as opposed to the interface between the window and the rest of the wall, however some occurrences were reported.

2.8 BUILDING REVIEW

In the course of the investigation, 50 buildings were reviewed. Each review was based on the following sequence;

- a general overview of the building,

- meeting with the onsite building manager, owner, or tenant to discuss the accuracy of the information previously reported, where possible,

- detailed inspection of the typical interior locations of moisture related damage, and

- detailed visual inspection of selected portions of the exterior to verify the method of construction and materials, and determine the probable sources of reported leakage.

3.0 RESULTS AND DATABASE ANALYSIS

The size of the database, and the procedures used for sampling do not permit detailed statistical analysis of the buildings reviewed. The database was based on buildings available for review and not a random sample of recent construction. This should be considered in interpreting the significance of the following data.

3.1 CLASSIFICATION OF BUILDINGS

In the data reported, "problem" buildings are those that have (or previously had) problems, many of which were known prior to this study and had already been repaired. "Non-problem" buildings are those that proved not to have problems upon examination. Where the B.C. study refers to buildings found not to have problems as "control" buildings they are referred to here as "non-problem" buildings. Neither study draws on a random sample of the total population. The methods used to recruit sample buildings for the two studies were different, so some comparisons of results will reflect this, not differences between the populations. The relative frequencies of the two classes, "problem" and "non-problem" are artifacts of selection in both cases. The kinds of problems observed, however, are not. Unfinished buildings, of which there were 13, are included as "non-problem" buildings in most of the data reported. Otherwise, they are explicitly shown separately as in Table 1. It is to be expected that some of these buildings may have problems after completion.

Table 1: Characteristics of Study Buildings

Statistic	Problem Buildings	Non- Problem Buildings	Unfinished Buildings	All Buildings
No. of Buildings	23	14	13	50
No. of Wall Types	27	14	13	54
No. of Problems	49	0	0	49

Excluding buildings from previous investigations and buildings under construction, the distribution is somewhat different, indicating that the bias in sampling has resulted in more problems than likely exist in the population. Even in this sub-sample there is a bias, since contacts with the steering committee resulted mainly in recruitment of problem buildings.

3.2 NUMBER OF UNITS & NUMBER OF STORIES

Three out of nine multi-unit buildings had problems, while seventeen out of forty-one single-unit buildings had problems.

The number of one, three, and four storey buildings were not large enough to support any conclusion about the influence of building height on problems.

3.3 AGE OF BUILDING

The mean time to discovery of a problem was zero (expressed in years). The year of completion ranged from 1990 to 1999, with too few buildings completed in any given year to allow any trend to be detected.

3.4 COST OF REPAIRS

Approximate cost to repair information was available on nine buildings, all of which were stucco-clad. On a per dwelling or unit basis the cost of repairs on these buildings ranged from $1,000.00 to $25,000.00.

3.5 WINDOWS

Prior to 1995 in coastal B.C., non-thermally broken aluminum windows with condensation gutters were common. More recent buildings in B.C. are likely to have thermally broken aluminum windows, and vinyl windows are also becoming more common. In Alberta, vinyl windows are currently the most common, followed by aluminum-clad wood. All Alberta windows have sealed double glazing, and few have condensation gutters. There is no clear relationship between the incidence of problems and type of window, as indicated by Table 2.

Table 2: Types of Window

Window Type	Problem Buildings	Non- Problem Buildings
Wood Clad		
- Hinged or Fixed	4	8
- Sliding	3	0
Vinyl		
- Hinged or Fixed	11	12
- Sliding	2	4
Other	3	3

3.6 WALL CONSTRUCTION

Stucco and vinyl siding were the only well represented cladding types. Buildings with vinyl siding appear to be less likely to have problems with exterior moisture, an observation that may be biased by ease of repair. It is easier to remove vinyl siding to do a repair, and so less likely that a problem would be remembered and reported. There may have been an additional bias to selection of problem buildings with stucco, since most of the files from previous investigations were related to this cladding type, while most of the vinyl-clad buildings were recruited without regard to problem status. Based on Table 3, the percentages of stucco walls with problems are consistently higher than the percentage of all walls with problems, for every combination of sheathing membrane and sheathing. Stucco walls with housewrap are also disproportionately problem walls.

Table 3: Indicators of Problem Walls by Type of Exterior Cladding, Moisture Barrier, and Sheathing (no. of walls with problems / total no. of walls of same type)

	Stucco	Vinyl	Other	Total
Building Paper & OSB	14/24	2/12	0/1	16/37
Building Paper & Plywood	1/2	0	0	1/2
Housewrap & OSB	7/10	0/2	1/1	8/13
Housewrap & Plywood	0/1	0/0	0/0	0/1
Other	0/0	0/1	0/0	0/1
Total	22/37	2/15	1/2	25/54

All but one of the walls had 140 mm framing with fibreglass batt insulation. Hence, there was no opportunity to compare the influence of framing size or amount of insulation on problems.

Table 4 shows the percent of walls that included various details on which data were collected. For instance, 16% of all problem walls had parapets, while only 3% of non-problem walls did. Nine percent of all walls had parapets, so problem walls had more than their share, an indication that parapets may be a problem. All of the parapets were flashed, but the design was judged poor for 25% of the problem walls. Data for details that seem significantly over-represented in problem walls are highlighted.

Table 4: Problem Occurrence and Quality of Details

P=Problem Walls NP=Non-problem Walls A=All Walls	% of Walls Having Detail			% of Details Flashed			% with Poor Design			% with Poor Material			% with Poor Installation		
	P	NP	All	P	NP	All	P	NP	All	P	NP	All	P	NP	All
Flat Roof Parapet	16	3	9	100	100	100	25	0	20	0	0	0	0	0	0
Soffit Sloping Toward Wall	16	3	9	25	0	20	75	100	80	0	0	0	0	0	0
Roof / Wall Junctions	92	97	94	100	100	100	0	0	0	0	0	0	0	0	0
Saddle (ex. Guardrails)	4	0	2	0	NA	0	100	NA	100	100	NA	100	0	NA	0
Decks	8	7	7	100	100	100	0	0	0	0	0	0	0	0	0
Balconies	84	93	89	67	96	83	43	4	21	0	0	0	0	0	0
Patios	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Exterior Walkways	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Exposed Columns	12	3	7	0	0	0	100	100	100	0	100	25	0	0	0
Horizontal Transitions	44	34	39	36	40	38	64	50	57	0	30	14	0	0	0
Window Sills	96	100	98	4	10	8	96	90	92	0	3	2	0	0	0
Window Heads	96	100	98	92	83	87	25	38	32	0	3	2	0	0	0
Dryer Vent	76	97	87	5	21	15	95	79	85	5	0	2	0	0	0
Other Vents & Inlets	88	97	93	5	18	12	95	79	86	5	0	2	0	0	0
Guardrail Attachment	16	0	7	0	NA	0	100	NA	100	0	NA	0	0	NA	0
Electrical Fixtures	88	100	94	5	7	6	95	93	94	5	0	2	0	0	0
Scuppers	16	3	9	50	100	60	75	0	60	0	0	0	0	0	0
Utility Lines	84	90	87	0	0	0	100	100	100	10	0	4	0	0	0
Eavestrough & Downspout	84	93	89	NA			10	0	4	10	0	4	0	0	0

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P=Problem Walls NP=Non-problem Walls A=All Walls	% of Walls Having Detail			% of Details Flashed			% with Poor Design			% with Poor Material			% with Poor Installation		
	P	NP	All	P	NP	All	P	NP	All	P	NP	All	P	NP	All
Flat Roof Parapet	16	3	9	100	100	100	25	0	20	0	0	0	0	0	0
Soffit Sloping Toward Wall	16	3	9	25	0	20	75	100	80	0	0	0	0	0	0
Roof / Wall Junctions	92	97	94	100	100	100	0	0	0	0	0	0	0	0	0
Saddle (ex. Guardrails)	4	0	2	0	NA	0	100	NA	100	100	NA	100	0	NA	0
Decks	8	7	7	100	100	100	0	0	0	0	0	0	0	0	0
Balconies	84	93	89	67	96	83	43	4	21	0	0	0	0	0	0
Patios	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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Window Sills	96	100	98	4	10	8	96	90	92	0	3	2	0	0	0
Window Heads	96	100	98	92	83	87	25	38	32	0	3	2	0	0	0
Dryer Vent	76	97	87	5	21	15	95	79	85	5	0	2	0	0	0
Other Vents & Inlets	88	97	93	5	18	12	95	79	86	5	0	2	0	0	0
Guardrail Attachment	16	0	7	0	NA	0	100	NA	100	0	NA	0	0	NA	0
Electrical Fixtures	88	100	94	5	7	6	95	93	94	5	0	2	0	0	0
Scuppers	16	3	9	50	100	60	75	0	60	0	0	0	0	0	0
Utility Lines	84	90	87	0	0	0	100	100	100	10	0	4	0	0	0
Eavestrough & Downspout	84	93	89	NA			10	0	4	10	0	4	0	0	0

Table 5 shows the number of times a particular class of problem was cited. The overall frequencies indicate that windows, doorways, and decks are where most problems occur.

Table 5: Indicators of Problem Categories by Type of Exterior Cladding and Construction Details (no. of citations)

	Stucco	Vinyl	Other	Total
Material / Installation Defects - Wall Section	3	0	0	3
Penetration: Poor Seal	3	1	0	4
Poor Base/Transition/ Control Joint Flashings	2	1	0	3
Poor Deck or Balcony Waterproofing - At Outer Edge	4	0	1	5
Poor Deck/Walkway/ Balcony Waterproofing - At Walls	8	1	0	9
Poor Deck/Walkway/ Balcony Waterproofing - Field	2	0	0	2
Poor Drainage / Eavestroughs / Downspouts	4	0	0	4
Poor Other Details	6	0	0	6
Poor Parapet/Guardrail Cap Flashings	4	0	0	4
Poor Roof/Wall Joint Flashings	2	0	0	2
Poor Vents: Interior Moisture	1	1	0	2
Window or Door: Leakage	4	0	0	4
Poor Vents: Exterior Moisture	0	0	0	0
Window or Door: Poor Flashing at Head	14	0	0	14
Window or Door: Poor Sill Flashing	13	0	0	13
Windows: Poor Seal at Corner Mitre Joints	2	0	0	2
Windows: Poor Seal at Frame/Cladding Joints	14	0	0	14
Windows: Poor Weather Barrier Installation	14	0	0	14
Total	100	4	1	105

3.7 AIR BARRIER LOCATION

If the cladding is stucco, the stucco is likely to be the most airtight element in the wall assembly. Vinyl siding is unlikely to be more airtight than the other element in the wall. Of the walls where the cladding appeared to be the most airtight element, twenty-two out of thirty-seven walls had problems. Where the interior finish appeared to be the most airtight element, three out of fifteen walls had problems. It seems likely that the lower incidence of problems reflects better pressure-equalization between front and back of the wetted surface, resulting in lower rates of water penetration through similar defects. Reporting of which layer was most airtight was based on judgement and visual observation, since measurements under windy conditions of pressure indoors, inside the wall cavity, and outside could not be made.

3.8 OVERHANGS & EXPOSURE

The majority of eaves were between 300 and 600 mm wide. Predominant wind driven rain is from the North and West throughout most of Alberta. North facing walls with minimal shielding were the most problematic. In Table 6 all problems are included, including those that would not be influenced by the overhang, such as leakage at the juncture of a deck or balcony with a wall.

Table 6: Eave Width and Cladding Type

Overhang, mm	No. of Stucco-Clad Walls	No. of Vinyl-Clad Walls	No. of Other Walls	Total
0	4	0	0	4/54
1 - 300	12	6	0	18/54
301 - 600	20	7	1	28/54
601 -	2	1	1	4/54
Total	38	14	2	54/54

Table 7: Relationship Between Problems, Eave Width and Cladding Type
(no. of problem walls / no. possible)

Overhang (mm)	Stucco	Vinyl	Other	Total
0	4/4	0/0	0/0	4/4
1 - 300	7/12	1/6	0/0	8/18
301 - 600	11/20	1/7	1/1	13/28
601 -	0/2	0/1	1/1	1/4

Table 8: Relationship Between Orientation and Eave Shielding for Problem Locations

Shielding	North	East	South	West	Total
Minimal	33	10	12	12	67
Low	6	3	4	5	18
Moderate	1	2	3	3	9
High	1	4	0	5	10
Total	41	19	19	25	104

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	Stucco	Vinyl	Other	Total
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Penetration: Poor Seal	3	1	0	4
Poor Base/Transition/ Control Joint Flashings	2	1	0	3
Poor Deck or Balcony Waterproofing - At Outer Edge	4	0	1	5
Poor Deck/Walkway/ Balcony Waterproofing - At Walls	5	1	0	6
Poor Deck/Walkway/ Balcony Waterproofing - Field	2	0	0	2
Poor Drainage / Eavestroughs / Downspouts	4	0	0	4
Poor Other Details	6	0	0	6
Poor Parapet/Guardrail Cap Flashings	4	0	0	4
Poor Roof/Wall Joint Flashings	2	0	0	2
Poor Vents: Interior Moisture	1	1	0	2
Window or Door: Leakage	4	0	0	4
Poor Vents: Exterior Moisture	0	0	0	0
Window or Door: Poor Flashing at Head	14	0	0	14
Window or Door: Poor Sill Flashing	13	0	0	13
Windows: Poor Seal at Corner Mitre Joints	2	0	0	2
Windows: Poor Seal at Frame/Cladding Joints	14	0	0	14
Windows: Poor Weather Barrier Installation	14	0	0	14
Total	100	4	1	105

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601 -	2	1	1	4/54
Total	38	14	2	54/54

Table 7: Relationship Between Problems, Eave Width and Cladding Type
(no. of problem walls / no. possible)

Overhang (mm)	Stucco	Vinyl	Other	Total
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301 - 600	11/20	1/7	1/1	13/28
601 -	0/2	0/1	1/1	1/4

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Low	6	3	4	5	18
Moderate	1	2	3	3	9
High	1	4	0	5	10
Total	41	19	19	25	104

3.9 LOCATIONS OF PROBLEMS

Although looking at the incidence of problems on buildings of different numbers of floors gave no indication of a trend, the locations where they were observed on buildings do indicate that problems, particularly at heads of openings, are less frequent on the first floor below the eave. Overhangs are most effective in shielding the top floor. Walls below balconies, even those clad with a waterproof layer, were susceptible to water leakage due to poor deck/wall junctions.

3.10 TIME OF OCCURRENCE

Although there were more stucco clad walls in the sample than vinyl clad, stucco-clad walls are still disproportionately susceptible to leakage under conditions of wind and rain in particular. Wind combined with rain is the weather condition most often associated with leakage for all walls.

Table 9: Weather Conditions When Problem Occurs

	Stucco	Vinyl	Other	Total
Rain Alone	9	0	1	10
Wind & Rain	38	2	1	41
Wet Snow	12	0	1	13
Thaw after Cold	6	1	0	7
Total	65	3	3	71

3.11 DETERIORATION

Compared to buildings studied in B.C., moisture related damage in Alberta is generally less severe, and much less likely to involve rot of sheathing or framing. In some cases, there was enough moisture present for rot to be a potential problem, however no cases were evident where fungi were active in the sheathing or framing. The most prevalent symptoms of damage observed were wetting and staining of interior finishes. Only those wall layers that showed damage are included in Table 10.

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Table 10: Symptoms of Damage

Material	Symptoms	No. of Cases
Cladding	stains decay cracking	8 6 3
Sheathing Membrane	rot	1
Sheathing	stains	1
Framing	saturation	2
Interior	stains saturation shrinkage or swelling cracking	33 1 1 6

Table 11: Severity of Damage

	Minor	Moderate	Severe
Stucco Clad Walls			
Cladding	5	11	1
Sheathing Membrane	0	0	1
Sheathing	0	1	1
Framing	0	1	1
Interior	18	18	2
Vinyl Clad Walls			
Interior	1	2	0

3.12 EXTERIOR MOISTURE

Exterior moisture was a contributing factor in 91% of problems. For cases where exterior moisture was involved, Table 12 shows the average percent contribution to exterior moisture-caused symptoms of different sources and paths of entry.

Table 12: Percent Contribution to Exterior Moisture-Caused Symptoms

	Stucco	Vinyl
Sources		
Direct Rain Penetration	76	100
Run-off	7	0
Splash	1	0
Ponding	5	0
Snow Melt	9	0
Other	2	0
Paths Through Face of Wall		
Failed Material		
Inherent Pores & Joints	30	0
Sealant	0	0
Cladding	1	0
Other	12	0
Penetrations		
Vent Hoods	0	0
Guardrails	0	0
Electrical Fixtures	0	0
Scuppers	2	0
Utilities	0	25
Other	1	0
Flashings		
Parapet	2	0
Roof / Wall	6	0
Saddle	1	0
Deck Exterior Edge	5	0
Deck Base	11	50
Material Transition	1	25
Window/Door Sill	13	0
Window/Door Head	11	0
Inherent Pores or Joints	1	0
Other	3	0
Path Through Secondary Water Barrier		
No Barrier	6	0
Discontinuities	22	25
Degradation	1	0
Laps	44	50
At Flashing	22	25
At Penetration	3	0
Other	2	0

Table 12: Percent Contribution to Exterior Moisture-Caused Symptoms

	Stucco	Vinyl
Sources		
Direct Rain Penetration	78	100
Run-off	7	0
Splash	1	0
Ponding	5	0
Snow Melt	6	0
Other	2	0
Paths Through Face of Wall		
Failed Material		
Inherent Pores & Joints	30	0
Sealant	0	0
Cladding	1	0
Other	12	0
Penetrations		
Vent Hoods	0	0
Guardrails	0	0
Electrical Fixtures	0	0
Scuppers	2	0
Utilities	0	25
Other	1	0
Flashings		
Parapet	2	0
Roof / Wall	6	0
Saddle	1	0
Deck Exterior Edge	5	0
Deck Base	11	50
Material Transition	1	25
Window/Door Sill	13	0
Window/Door Head	11	0
Inherent Pores or Joints	1	0
Other	3	0
Path Through Secondary Water Barrier		
No Barrier	6	0
Discontinuities	22	25
Degradation	1	0
Laps	44	50
At Flashing	22	25
At Penetration	3	0
Other	2	0

3.13 INTERIOR MOISTURE & CONSTRUCTION MOISTURE

Condensation moisture from indoor air contributed to 14% of all problems. In all cases, it appeared that the problem was due to occupants who tried to maintain indoor humidity at levels above 30% through the winter for health and comfort or because of concerns about furniture and floors. Most residential buildings cannot perform adequately with relative humidities greater than 30% during cold exterior conditions.

In no case could construction moisture be identified as a contributing factor.

3.14 RESPONSIBILITY FOR PROBLEMS

All problems were categorized according to how much design, quality of materials used, installation, and maintenance had contributed to the onset of problems. Construction and design of stucco walls were significant contributors to the problems observed. Improper maintenance and operation contributed minimally due to the age of the walls. More than one cause could be cited for a given problem.

Table 13: Contribution of Design, Material, Installation, and Maintenance to Problems
(no. of citations / no. possible)

	Stucco	Vinyl	Other
Design	20/45	1/3	1/1
Construction	42/45	3/3	1/1
Maintenance	3/45	0/3	0/1
Operation	5/45	0/3	0/1

3.15 SUMMARY

- Stucco clad buildings are more likely to have significant moisture problems than vinyl clad buildings.

- The most common and severe moisture problems are at perimeters of windows and doors, and where decks adjoin walls. Both cladding types are equally likely to have problems with decks. Stucco is more likely than vinyl to have problems at window and door perimeters, and the problems are on average more severe.

- Parapets rather than eaves at roof edges, soffits that slope down to the wall, exposed columns, vertical transitions, rail attachments, and scuppers are details disproportionately associated with problem walls.

- Compared to buildings included in the B.C. study, resulting damage from moisture, particularly to sheathing and framing, is less severe in Alberta.

- Exterior moisture sources predominate.

- North and West facing walls with minimal shielding are more likely to experience leakage during wind and rain.

- Construction and design are the most common factors contributing to problems.

4.0 DISCUSSION & RECOMMENDATIONS

4.1 WHY NOW?

4.1.1 WAS THE PAST PROBLEM FREE? ARE SOME CURRENT PROBLEMS JUST EXTENSIONS OF THE PAST?

Minor water leakage through walls of some houses has always occurred. On the West coast, the Division of Building Research was receiving many requests for assistance with leaks around windows 15 years ago (see Ref. 6). Water leakage has been experienced through walls and windows of many medium-rise residential buildings constructed over the past 25 years in Alberta, after each significant wind driven rain. Thin stucco, poor quality sand, lack of understanding on the part of designers, workers, and supervisors, and windows that leak in exposed locations are not new problems.

4.1.2 WHAT HAS CHANGED IN THE LAST 10 YEARS?

In addition to actual changes in buildings, the expectations of building occupants may be higher now than in the past. This was certainly a factor in cases where indoor humidity contributed to moisture problems observed in the study.

Exposure is on average more severe than in the past, as buildings are becoming taller. Even single family houses are taller. One storey walls were once the norm, while 2 to 3 storey walls are now the norm, with more walkout basements and exposed locations. At the same time, overhangs tend to be smaller, especially in proportion to wall height.

Windows with brick molds are rare, and almost all windows now have nailing flanges instead. Window sections are smaller. There are no drip caps, sills don't always slope, and sills and head flashings rarely have adequately projected drips and slope.

Vinyl windows are now the most common type, and have increased their market share substantially over the last 10 years. One Calgary manufacturer of both vinyl and metal clad wood windows reported that approximately 60% of their sales are vinyl. Vinyl windows were used on 29 of the 50 buildings observed.

Large windows, and arrays of several windows stacked, or placed side by side (or both), in a single opening, are becoming more common. Windows with curved heads are also more common.

Because the pace of change in materials and practices has increased, and is changing at an increasing rate, workers need to have a better understanding of how things work together. If anything, they may have less experience and less understanding now than in the past when the industry was smaller, simpler, and changing less rapidly.

While there has been a major change from dimension lumber to engineered wood joists for floors, it is likely that the change has reduced the risk of distress in cladding rather than increased it. In the buildings observed, there was only one case where distress in stucco might have been due to shrinkage of the framing.

Building paper was previously wrapped into the window rough opening, the window installed, the perimeter gap stuffed with batt insulation and the paper folded into the window interior and sealed to the wood extension. Currently a 150 mm wide strip is typically installed on the sheathing around the edges of the rough window opening, with no intention of sealing. The paper is folded over at corners, and covered over by primary building paper after the window is installed.

As buildings have become larger, particularly with condominiums, the exposure of walls has increased. Larger multi-unit buildings have become more complex, so they introduce details that are otherwise uncommon, and increase the number of occurrences of each detail.

4.1.3 WHAT WILL THE FUTURE BRING?

The future will most likely bring more of the same. Until problems appear, each segment of the industry seems to concentrate on improving productivity and reducing cost within its own confines. When costs cannot be reduced overall, it is sometimes possible to find a way of handing them off to someone else, not always intentionally. For instance, smaller window sections without drips reduce the cost of the window, but increase the eventual cost of the building when adaptations to flashings and cladding, and repairs to eventual damage are totaled. These mechanisms, not a desire for improved building performance, have driven the changes of the last 10 years and will continue to exert pressure for change in the industry. Few industry participants are unprincipled opportunists, but the pressure is always there and it is

easy for specialists not to see the full ramifications of changes in their design, materials, and installation practices.

4.2 PROBLEMS AND RECOMMENDATIONS

4.2.1 CONTROL OF RAIN PENETRATION

Rain leakage occurs as a result of 3 factors; water on the wall, paths for the water to penetrate the wall surface, and forces to drive the water inward. Paths for water to penetrate the wall cannot be entirely eliminated. If they are not there to begin with, thermal movement and weathering will introduce them in time. Some walls are protected from water on the surface, in recesses or porches, or under eaves. However most walls are wetted and have paths through the wetted surfaces, so the following driving forces must be controlled:

- momentum,
- gravity,
- capillary suction, and
- air pressure difference across the wall.

Momentum is a problem only when a wind-driven raindrop hits a hole or crack. It can be controlled by minimizing incidental holes and cracks, and by baffling necessary openings and joints. A cavity behind the wetted surface, constructed to the rainscreen principle with venting, drainage and an effective air barrier, will intercept gravity-driven flow, will moderate air pressure differences across the wetted exterior surface, provide a capillary break, and prevent the wall surface behind it from being wetted. In addition, any water that does penetrate the first line of defense can drain back out. If the sheathing membrane is building paper, it should not be sealed air tight for improved venting. Where the rainscreen is interrupted:

- install outward sloping flashings at horizontal junctions between different materials and over doors and windows,
- seal or baffle vertical joints,
- terminate cladding 10 mm or more above horizontal surfaces of flashings to allow for drainage, and
- terminate cladding 100 mm or more above horizontal surfaces of roofs and decks.

Where water is concentrated on the surface, it should be directed to less vulnerable parts of the wall (away from joints between materials, for instance), and encouraged to fall clear of the wall using drip edges. Vents into the cavity should be located at either the bottom, where there is a flashing, or else protected from water so that gravity will not lead water through them into the upper parts of the cavity.

4.2.2 TRAINING

Although at least one Alberta institution offers a training program for plasterers, there is no requirement for formal training of workers who install sheathing membranes, stucco, or siding. Glazing apprenticeship programs are available, however, few framers would be involved in such a course, and the framers rather than glaziers install windows. Most workers learn by example, without the benefit of formal training.

4.2.3 FRAMING

Wood shrinks as it dries, and edges of sheathing materials swell when wet. The change from dimensional lumber to engineered wood for floor structures has probably reduced the incidence of damage to cladding caused by framing shrinkage. Studs shrink in length about the same amount as stucco shrinks when curing, 3 mm or so in a 2.5 m high wall. A double 38 mm plate, shrinking across the grain, will shrink about 4 mm. A 300 mm engineered wood joist will shrink about 2 mm, assuming that it is relatively dry initially. These movements may cause distress in stucco, or cause decks that were installed sloping away from the building to slope toward it. Movement can be limited by detailing to avoid double sill plates.

4.2.4 BUILDING PAPER, HOUSEWRAPS & MEMBRANES

4.2.4.1 Impregnated Papers

Most building paper used in Alberta is asphalt-impregnated Kraft paper that conforms to CGSB- 51.32-M77, "Sheathing Membrane, Breather Type". This paper meets the requirements of the Alberta Building Code, 1997, (ABC) for sheathing membranes (in paragraph 9.23.17). The CGSB standard is intended to describe a breathing membrane to act as a secondary protective covering under cladding, to retard entry of wind and moisture. It does not require the product to be tested for water resistance, however, does test for tensile strength and pliability. The permeance requirements are listed in Table 14.

Table 14: Permeance of CGSB Sheathing Membrane, Breather Type (Building Paper)

Vapour Permeance	170 - 1400 ng/Pa*s*m^2 (1.95 - 16 Metric Perms)
Aged Vapour Permeance	2900 ng/Pa*s*m^2 (33 Metric Perms)

The ABC requires sheathing membrane ("sheathing paper" in the code) to be building paper conforming to the CGSB standard. In contrast, some B.C. jurisdictions commonly call for building paper to have a minimum minute rating based on ASTM D779-94, known as the "boat test" as well.

Water resistance of building paper sold in Alberta is not specified by the manufacturers. It is likely that the ASTM rating of typical single weight (125 g/m^2) paper meeting the CGSB requirements is 10 minutes. Heavier papers are available, with lower vapour permeances and higher water resistance, but are rarely used.

The ASTM standard states that for times longer than 30 seconds the test is not a valid measure of liquid resistance. Instead, it measures vapour permeance indirectly.

Table 15 includes several types of paper used as sheathing membranes, most of which are used primarily in B.C. The 2-ply corrugated paper is used to create a 4 mm cavity for drainage.

For designs with strapping added to create a vented drainage layer, B.C. paper manufacturers also offer a 3 ply, relatively rigid board with water resistance in excess of 10 hours and permeance of 44 - 130 ng/Pa*s*m^2 (less than the CGSB minimum), for placement over the strapping.

There is a direct trade-off between water resistance and vapour permeance of asphalt-impregnated building papers. This means that as water resistance increases, resistance to drying also increases.

Table 15: Building Paper Properties

Paper	Mass, g/m^2	Water Resistance, minutes	Vapour Permeance, ng/Pa*s*m^2
Building Paper	125	10 ±	970
30 min. Paper	178	30 - 45	420
60 min. Paper	273	60 - 90	320
2-Ply 30 min. Paper	479	210 - 240	260 - 300
2-Ply Corrugated Paper	479	150 - 180	260 - 300

4.2.4.1.1 Problems

The most evident problem is lack of understanding of the water shedding function of the sheathing membrane on the part of applicators. Problems that are the result of this lack of understanding include the following:

- reversed laps, even in the middle of a wall, but particularly at penetrations,
- rips and tears left unrepaired,
- use of incompatible tapes, and
- folds oriented to trap draining water.

Exposure to weather and UV damage during construction are other common problems, particularly where application of stucco has to wait for suitable weather. It is difficult to say how long membranes can be left exposed. Thirty days is probably acceptable, however, a full winter is normally too long. Double layering of paper will reduce the effect of exposure.

Construction damage, especially where gaps or changes of plane occur in the sheathing is another problem that results from delay in application of stucco. The single most desirable improvement in the paper itself, as opposed to how it is applied, would be improved flexibility and resistance to tearing and puncture (housewraps are better in this regard). Because building paper tears easily when folding is required, some builders use housewrap at details, with building paper on most of the wall. This often results in inadequate and reversed laps between the two materials.

Tape designed for use with housewrap is used extensively with building paper, to attach it to window flanges, secure butt joints, patch holes, seal reverse laps, and

to wrap penetrations. This probably seems reasonable to applicators, since the initial tack is very aggressive. However, tape is often applied to wet, frosty, or dirty surfaces to which it will bond poorly. It has not been tested for compatibility with anything other than housewrap. Durability of tape used for these purposes is unknown (but suspected to be less than the service life of the home). Even on housewrap, peel strength below -10 °C is not tested. There is no assurance that the tape is suitable for joining other materials, and from observation it does not adhere reliably to vinyl windows or building paper.

The sheathing membrane provides the secondary line of waterproofing in a wall. In coastal B.C., 60 minute paper is often recommended, however due to difficulties in working with a thick layer, two layers of 30 minute are commonly used. Albertans mostly use 1 or 2 layers of ordinary 10 minute building paper.

4.2.4.1.2 Recommendations for Retrofits

Where problems occur, remove cladding and add another layer of paper ensuring that proper laps are maintained, by installing from the bottom up, including penetrations.

If leaks are occurring at penetrations, remove the existing paper around the opening, seal the penetration to the sheathing with a peel-and-stick membrane (if compatible), and then install new paper, correctly lapped with the old paper and over the peel-and-stick membrane. Peel-and-stick membrane should not be adhered to building paper, or interleaved with it, except at the bottom of the opening, where the first course of paper should be underneath the peel-and-stick. Water can still leak past the peel-and-stick at jambs if it travels laterally, but no more so than at end laps in building paper.

If removal of the cladding is not an attractive option, put additional cladding over the original cladding with a drainage layer between.

4.2.4.1.3 Recommendations for New Construction

Adding more vapour diffusion resistance to the exterior of the wall reduces the slope of the vapour pressure gradient across the space inside the wall and reduces drying. Rain in Alberta is less frequent than in coastal B.C., and occurs when drying conditions in following days are likely to be good, therefore reduced drying potential seems inadvisable. Another consideration with less vapour permeable sheathing membrane is that indoor humidity with low exterior temperatures and air leakage add moisture to wall cavities to a greater extent in Alberta than in B.C.

Water resistance of building paper itself does not appear to be inadequate. Most of the paper-related problems stem from application practices or exposure to weather prior to installation of cladding. Stronger paper might be helpful, and two offset layers under stucco may be a good idea, but increased water resistance is not likely required. Continue to use standard building paper.

Lap paper to shed water, taking special care to lap over vertical legs of flashings, and under flanges or flashings at bottoms of penetrations. The importance of getting the paper lapped under window flanges at the sill (or rough sill flashings) cannot be overemphasized. Do not use tape to patch paper together, seal it to flanges of penetrations, or to mask non-shingled laps.

Two layers of building paper are recommended if it will be exposed for more than 30 days. In Edmonton this seems to be common practice, but not in Calgary.

4.2.4.2 Housewraps

There are two basic types of housewrap used as sheathing membrane instead of building paper on an equivalence basis, usually supported by Canadian Construction Materials Centre (CCMC) evaluations. Spunbonded wraps are mats of randomly oriented polyolefin fibres fused where they intersect. The pores are small enough that surface tension prevents passage of water, and even resists significant water pressure, but large enough for water vapour to pass with little resistance. Perforated polyethylene incorporates a continuous plastic film with perforations, small enough to exclude water normally but not small enough to resist much hydrostatic pressure. The films are relatively impervious to vapour, so overall permeance depends on the proportion of hole area to total area.

Spunbonded housewraps appear to perform poorly when tested to ASTM D779. Water vapour passes through easily, resulting in unimpressive "water resistance" ratings. However, if "water resistance" is defined as resistance to hydrostatic head, spunbonded membranes perform better than perforated wraps and building paper. The reported water resistance of perforated housewrap is low enough that wind pressure could force water through the perforations.

Table 16: Water Resistance of Membranes
(from spunbonded housewrap sales literature)

Material	Water Resistance, mm Head of Water
Heavy Spunbonded Wrap	280
60 Minute Paper	125
Perforated Housewrap	25

Housewraps are more permeable to vapour, and stronger than building papers in dry cup test conditions.

Table 17: Vapour Permeability of Housewraps and Building Papers

Material	Vapour Permeance, ng/ Pa*s*m^2
CCMC Listed Spunbonded Wraps	1500 - 7020
CCMC Listed Perforated Wraps	259 - 690
60 Minute Paper	240
Building Paper	970

4.2.4.2.1 Problems

Addition of surfactants to stucco mixes may have adverse effects on the performance of housewrap, especially when bonded to (hence in capillary contact with) porous cladding. Like all barriers that depend on surface tension, including building papers to some extent as well, both spunbonded and perforated film housewraps resist water less effectively when combined with a surfactant. It is likely that the properties of housewraps change more dramatically when this occurs than do the properties of building paper.

Vapour permeance is a mixed blessing. Spunbonded housewraps retard vapour flow less than building paper under most conditions. Combined with their strength, this is a property that designers can exploit to their advantage. However, reverse vapour flow, when vapour pressure is higher on the outside, should be considered if housewrap is substituted for less permeable building paper. Although water that leaks into the wall or condenses there during the winter will dry out more rapidly, more condensation will occur on the exterior surface of the vapour barrier with

spunbonded housewrap than with building paper when porous cladding like exterior brick or stucco is saturated with water and warmed by the sun. This may or may not be a problem, depending on the climate, but should be considered.

In addition, it is our understanding that at higher humidities on the wet side, the permeance of asphalt impregnated papers increases significantly, and can be substantially higher than that of spunbonded housewrap when the humidity is above 80% on the wet side.

It has been reported that housewraps do not wrinkle when wet and also bond to stucco. Building papers are reported to wrinkle to form small voids between the paper and stucco which allow for drainage, and to be less likely to bond to stucco. Further research is required to evaluate the significance of these reports.

4.2.4.2.2 Recommendations From the Literature

To improve performance under stucco, one manufacturer has introduced a spunbonded wrap that is creped, for use with stucco, and reports that because it does not wrinkle when wet, and does not absorb water needed for hydration, less cracking occurs in the stucco base coat when it is used. In addition, the texture of the product is reported to promote drainage.

Air pressure differences on wetted surfaces can force water through perforations of perforated wraps.

Use building paper underneath a creped spunbonded wrap when stucco is applied directly, to provide better air-seal and water shedding than paper alone, but still retard reverse vapour flow. (see Energy Design Update (EDU), August 1998, Ref. 13).

4.2.4.2.3 Recommendations for New Construction

In general, perforated wraps without building paper backup should not be used where they are wetted and subjected to an air pressure difference.

Further research is required into the effectiveness of spunbonded housewraps under stucco. Furring or an air space may solve drainage, adhesion, and surfactant problems, but not reverse vapour flow. The significance of differences between paper and housewraps requires additional research.

4.2.4.3 Peel & Stick Membranes

Peel-and-stick membranes (self adhering membranes) are usually SBS-modified asphalt coated on a polyethylene carrier sheet. They are vapour resistant and waterproof, provided that joints are sealed. They are substantially self-sealing around fasteners.

To be effective, a peel-and-stick membrane has to be fully bonded to the substrate. The use of a primer is recommended.

Peel-and-stick membranes make good flashings, if adhered, supported and protected, but can trap condensation if applied on the cold side of a wall assembly. They are more expensive than paper flashings, require a time delay after priming, will deteriorate with long term UV exposure, and should not be applied at temperatures below freezing. Substrates must be clean, dry and free of frost.

4.2.4.3.1 Problems

Peel-and-stick membranes observed were used mostly in retrofits. The repairs often showed a lack of understanding of the material and installation requirements. Where used on the buildings investigated, the membrane was often applied over building paper, occasionally secured with staples, applied to unprimed surfaces, inadequately rolled smooth, and installed with non-shingled laps.

4.2.4.3.2 Recommendations

Peel-and-stick membranes will improve the window perimeter water seal to the sheathing. However, if peel-and-stick membrane is adhered to a window sill flange and to the sheathing, it will trap water that may leak through joints in the window frame.

When peel-and-stick membrane is used, it should be limited to strips of flashing around openings, adhered to the sheathing and window flanges on heads and jambs, and into the sill to form a trough into the rough opening behind the nailing flange. Used in this way, peel-and-stick membranes do not prevent entry of water into the wall if there is a force (like wind) to move it laterally past the edge of the flashing, but they do increase the lap between the sheathing membrane and the window flange. Below an opening, peel-and-stick should lap over the sheathing membrane (this may require leaving the release paper on the peel-and-stick membrane for the width of the lap). If peel-and-stick membrane is adhered to the window sill flange, and the rough sill is flashed and drained, some means of allowing drainage of the rough sill behind the membrane on the flange (or through

the flange) is required. Providing an interior air seal between the window frame and gypsum board is required to prevent air and water leakage up through the sill cavity.

Detail 13 ADA of the Best Practice Guide: Wood Frame Envelopes in the Coastal Climate of British Columbia (see Ref. 21 and Appendix A), provides a window sill section detail sealed using a similar procedure, except that the jambs and head are also wrapped with peel-and-stick membrane before the window is installed. The detail provides an effective means of air tightness for the window assembly, which may also be provided by an alternate means.

For all peel-and-stick membrane installations, the substrate must be sound, compatible, and primed, and laps between pieces of peel-and-stick membrane should still be made to shed water.

If a peel-and-stick membrane is used instead of a vapour permeable sheathing membrane over a large area or an entire wall, as was seen on one building retrofit, then at minimum the wall cavity requires vents extending through the membrane to the exterior. This solution is not recommended, since to prevent condensation might, in addition, require added insulation on the exterior (to move the interior dewpoint temperature outward of the membrane). With vents through the membrane, some parts of the stud space may still not be vented adequately. Furring and a pressure equalized, drained airspace is preferable, but there may not be enough room for it in a retrofit situation.

4.2.5 CLADDING

4.2.5.1 Vinyl Siding

4.2.5.1.1 Properties

Vinyl siding is reasonably durable, attractive, and maintenance free. The siding profile provides an air space behind the cladding, and ventilation to the exterior. With some attention to detail, the air space can be pressure-equalized and drained to improve resistance to wind-driven rain at little additional cost. Vinyl is not porous, and the air space breaks most, if not all, capillary paths from the wetted exterior surface to the surface of the sheathing membrane.

Vinyl siding has high thermal expansion and contraction which have to be accommodated.

Vinyl siding is relatively easy to remove and replace to allow for repair of problems behind the cladding, compared to stucco. It is likely that the air space behind the surface is also a significant factor.

4.2.5.1.2 Problems

Standard vinyl siding accessories don't include a satisfactory flashing for heads of windows, doors and other penetrations. J-trim used at the head collects water and concentrates drainage at corners of openings or at joints in the trim. Flashings beneath the J-mold are often omitted, and joints used at the corners don't direct water away from the vulnerable juncture at the jamb. The joints are sometimes mitred, or notched and bent. Extending the trim at the head beyond the jambs, and butting the jamb trim to the underside of the extension is preferable to a notched and bent continuous trim.

Drain and vent holes are required by CCMC, although in most vinyl siding the holes are small and may be ineffective for drainage, as opposed to ventilation. Venting and drainage also occurs through the lap joints. Viewed from the back, there are often gutters in the profile which can intercept water draining down the face of the sheathing membrane and concentrate it at end joints.

Joints between siding and trims cannot be sealed with caulking, because of high thermal movement.

4.2.5.1.3 Recommendations

Minor modifications of trim and siding sections would make the system as a whole perform as a more effective rain screen. Performance evaluations should include the siding, trim, and details as a coordinated system, similar to other cladding systems.

Install head flashings at openings, extending to the lip of the J-mold on the jamb (that is, extending past the window jamb to the visible edge of the J-mold). Perforate the J-mold so that it drains water onto the head flashing installed below, instead of acting as a gutter and concentrating it at the jamb connection.

Install sill flashings with drips at all openings. Extend sill flashings to the lip of the J-mold at the jambs, to direct water at the jamb J-mold to the exterior at the sill

Caulking the joint between the jamb and the J-mold is beneficial, to minimize direct water penetration to the sheathing membrane.

Install dryer vents and hose bibs so they can be replaced without removal of siding, using details that exclude water entry.

4.2.5.2 Stucco

4.2.5.2.1 Properties

When completed in accordance with ABC requirements, stucco base coat is site-batched using masonry sand, portland cement or masonry cement, and hydrated lime. The finish coat can incorporate non-fading mineral pigment as well.

It is reported by the Alberta Wall and Ceiling Bureau (see Ref. 9), based on tests, that:

> "Stucco is water resistant. Testing of a cement plaster basecoat has shown that when properly mixed and applied and adequately cured, a 3/4 inch (19 mm) cement plaster membrane is vapour permeable but is not water-permeable."

However, they also state that:

> "The stucco assembly is not recommended for tops of railings, tops of fences or tops of parapet walls" and "Surfaces in a plane less than 6:12 must be given special protection from the possibility of moisture intrusion".

Stucco properly mixed and cured provides a substantial degree of water resistance. However, it cannot be relied upon to be water tight (otherwise, it would be recommended for roofs and other horizontal surfaces). In addition, typical site-mixed stucco is assumed to be less resistant to passage of water than properly mixed, applied, and cured stucco.

Because it is porous and rough in surface texture, water that impinges on the surface may be held in capillary spaces rather than draining onto places that would leak. This property can prevent or reduce leakage during rains of short duration,

because the water held in the surface evaporates before it penetrates the stucco.

4.2.5.2.2 Problems

To make the material lighter and easier to apply, additives that do little to promote desirable properties in the cured stucco are often added. Application labour is reduced if the density is reduced by entrained air, and if the material is made slippery and cohesive in the plastic state. Additives often used include detergent, commercial air-entrainment additives, bentonite (sodium montmorillonite) clay, and commercial pumping aids.

Based on observations made during this study, rain water appears to permeate through stucco. Several observed buildings had experienced leakage where no direct paths for moisture to enter the wall were apparent from the exterior. One house in particular had a one storey high wall, with an adequate roof overhang. The stucco surface appeared to be sound with minimal cracks. There were no penetrations through the wall, however water leakage was documented flowing through to the interior during wind-driven rain and wet snow. The only apparent path through the exterior face of the wall was through porosity or microscopic cracking of the stucco itself.

It appears that stucco is improperly mixed, applied, cured and installed to less than 19 mm thickness relatively often. Materials that are not listed as stucco ingredients in Part 9 of the ABC are frequently added. Liquid will permeate through stucco, by means of capillary action through the cracks and voids that are more likely to occur as a result of improper mix proportions, application and curing procedures, and thickness. Stucco that is low on cement, too absorptive, or improperly cured is more susceptible to freeze-thaw damage.

Most stucco base and brown coats are field mixed in Alberta. It was reported by a manufacturer of stucco materials that Alberta stucco often has a problem with inadequately graded and impure sand and high sand to cement ratios (encouraged by economics) both contributing to higher permeability and absorption.

Controlling the stucco site mix, using only manufacturer's recommended and code approved additives, will improve the stucco mix, reduce cracking, increase strength and decrease water permeability. Soap has been added to some mixes to improve workability, however it entrains large air bubbles which increase porosity and water absorption while reducing strength. Adding bentonite clay makes the mix more workable, but also reduces strength and increases water absorption, although not

as much as soap. Soap also encourages wetting and leaking through sheathing membranes because it decreases surface tension. Some lime replacement additives cause very aggressive air entrainment and increased porosity. Incorrect field mixing, lesser quality materials, and use of some additives can significantly decrease the quality of stucco.

The two-coat method of application of stucco may contribute to water penetration. Typically base coats will experience shrinkage cracks in line with wires in the reinforcement. Cracks are larger where poor mixes and excess water are used. A second coat (brown coat) is required to seal the cracks. Since the cracks do not appear immediately, doubling back (to apply the second coat before the first coat has cured) increases the potential for cracks to extend through the entire base. Application of a finish coat hides the cracks, but they still increase the potential for water penetration. Two coat applications are very common, almost universal, in Alberta. Significant cracking through the finish coat was generally not observed, but cracks in stucco completed except for the finish coat are common.

Adequate curing of stucco is rare. Alberta's relatively dry and windy climate increases the potential for shrinkage cracking during curing. Removal of water by evaporation before hydration is complete, permanently weakens the material. Misting of stucco from time of application until it has cured is not common in Alberta.

Thinner stucco sections have less resistance to rain water penetration. The ABC requires a three-coat stucco application consisting of 6 mm minimum scratch coat, 6 mm minimum brown coat and a finish coat for an overall thickness not less than 15 mm. Alternatively, a two-coat application totaling 19 mm minimum thickness is permitted. Observed stucco application thicknesses of 13 to 16 mm are typical, and trims most often used provide for a thickness of 12 mm from the mounting surface to the surface of the screed.

Although stucco will provide a degree of water resistance, depending on the quality of the mix and application, some moisture penetration through it is to be anticipated and designed for.

Other problems noted include the following.

- Self-furring dimples in wire, given usual methods of fastening (the wire is fastened midway between dimples), result in much of the wire being flat

against the sheathing membrane, not in the middle of the stucco section, reducing the effectiveness of the wire.

- Although drainage behind the stucco is somewhat limited, both with building paper and with housewraps, it is sufficient to allow leakage when the space between the stucco and the sheathing is drained to the interior.

- Stucco trim available off the shelf does not allow for application at the minimum thickness prescribed by code. A typical J-mold has a depth of 12 mm, which means the stucco will be around 15 mm thick, if the mold is applied over the wire and the stucco is struck flush. (J-mold designed for greater thickness may be available, but was not used on the buildings studied).

- Stucco makes it difficult to repair problems underneath and patch seamlessly.

- Horizontal projections and surfaces are often used without protection. Water and snow are captured by projections, and water that would drip from a flashing often streaks down the wall below instead.

- Stucco has commonly been extended onto and bonded to the foundation wall in the past. Some of the study buildings were done this way (trapping water as a result in at least one case). More commonly a J-mold or stucco stop was installed at the base of walls and at horizontal transitions.

- Anchors fastened through the sheathing and sheathing membrane for scaffolding, are typically left in place and covered by the stucco. The anchors result in reduced stucco covering thickness, and may contribute to cracking and corrosion induced spalling. The anchors may also provide an additional path of water ingress through the sheathing membrane.

4.2.5.2.3 Recommendations

Installation of a rainscreen stucco assembly is recommended for all high exposure locations.

Although both quality and thickness of stucco are often less than current code requirements, these defects do not contribute as much to leakage as improper application of the sheathing membrane and protection at penetrations.

Use high quality materials. In one building reviewed, the quality of the stucco was so poor that one freeze thaw cycle while saturated could reduce it to sand, and pieces of the material that were not frost-damaged could be comfortably crumbled by hand. Use sand conforming to ABC requirements (a material supplier interviewed reported that this adds about $12.00 to the cost of a house), proportion the mix in accordance with code requirements, and don't use anything other than sand, cement, mineral oxide pigment, and lime in site-mixes. If air entrainment is used, use a commercial additive that has been tested to demonstrate that it does not have detrimental effects on durability and strength. Other additives, if any, should be shown to have no adverse effects on the quality of the finished product, or (like fiber reinforcement) to improve the product and it's performance relative to other components.

Slope projecting stucco surfaces 45 degrees or more, and add a flashing if the slope is less or if horizontal projection exceeds 50 mm. At the very least, slope exposed surfaces the minimum 6:12 recommended in the Stucco Resource Guide (see Ref. 9) and use sloped stucco surfaces only for ledges, not tops of parapets or walls.

Use two layers of sheathing membrane, normally building paper, under stucco. Consider using only housewraps designed specifically for use with stucco. The proper use of housewraps with stucco requires additional research.

Use a drip flashing as well as a J-mold at the bottom edge of the stucco, so that water draining down the surface of the sheathing membrane is led to the outside, to drip away from the wall surface. Ensure that the leg of at least the flashing, if not the J-mold is long enough to permit fastening to wood, while maintaining an adequate lap over the foundation. Use the same detail at horizontal joints between stucco panels, if frame shrinkage is expected to cause a problem requiring horizontal "expansion" joints, instead of conventional W-joints. If shrinkage is only a few millimeters, the stucco will probably accommodate the movement without a joint. If it is more, buckling and cracking may occur despite the "expansion" joint, and more water will get behind the stucco at the joint, especially at intersections with vertical joints.

4.2.6 Flashings

Metal flashings have to be taken as they come from building supply yards, or custom fabricated. A typical off-the-shelf window head flashing has a vertical leg of 40 mm (compared to the 50 mm minimum required by ABC 9.27.3.2.3 (see Ref.

19)) and has a horizontal projection of only 32 mm, which is often too little to provide an effective drip over window or door frames. Metal flashings often have no slope as fabricated or installed.

4.2.6.1 Problems

Standard flashing sections are almost never adequate, and should conform to the code. They typically have:

- ineffective drips,
- insufficient overhang,
- insufficient rise (40 mm rather than 50 mm (the ABC minimum) or more),
- lap joints that are not sealed,
- curved flashings that are created on site by notching the vertical leg of a typical flashing, and
- horizontal surfaces that are not sloped or that slope the wrong way.

Window head flashings are usually installed with horizontal surfaces that collect water and drain it down one jamb or the other, concentrating water at the joint between the window jamb and cladding. This makes any defect in the joint at the jamb more serious. If the flashing were sloped outward, with a drip edge far enough from the surface of the window head to prevent contact with droplets on the drip edge, the water that is otherwise concentrated at the jambs would fall free instead. Head flashings never have end dams, and are often truncated at the line of the jamb, although they are sometimes extended up to 15 mm past the jamb into the cladding. Extending flashings into the stucco may cause minor cracks, however will reduce leakage at the juncture between cladding and jamb by reducing the amount of water reaching that joint.

4.2.6.2 Recommendations

Slope horizontal legs of flashings a minimum of 30 degrees, to drain outward, and provide a space of at least 6 mm between the drip edge and the vertical surface behind it. Extend flashings a minimum 25 mm beyond the jambs to the edge of the window flange or vinyl J-mold, to reduce the potential for leakage into the jamb junction with the cladding. Leave a 5 mm tab at the end of the sloped leg to be turned up to form an end dam.

Fabricate vertical legs of flashings a minimum of 100 mm high, particularly for severe exposures. Although the code requires only 50 mm, the rationale is not

clear. Why is paper required to lap 100 mm when window flanges and flashings are not? A 140 km/h wind (1/10 hourly design wind in Calgary) results in a pressure difference between the interior and the windward exterior side of a building of 1000 Pa at an elevation of 5 m above grade, equivalent to a 100 mm head of water. A wind of about 90 km/h is sufficient to lift water under specific conditions over the 40 mm leg of the usual flashing. If the cladding is the most airtight plane of the wall, as it is in most stucco applications, most of this pressure is available to force water into the wall.

Install flashings at the base of the cladding, and in horizontal joints, to lead water draining down the sheathing membrane to the exterior, where it can drip clear of the wall below.

Avoid lap joints in flashings where possible. When they are required, lap them by 50 mm and seal them with an appropriate sealant.

If a curved flashing is required, ensure that the vertical leg is continuous, or lapped and sealed at the joints, not cut to the base to allow segments of straight flashing to be bent, or plan to counter flash it with a peel-and-stick membrane. Curved window heads should be supplied with matching stretch-formed flashings.

4.2.7 WINDOWS & DOORS

4.2.7.1 General

4.2.7.1.1 Properties

Almost all windows and doors now used have nailing flanges, rather than brick molds and drip caps. The same profiles are used for sill, head, and jambs of windows. Compared to older windows, the sections are smaller.

4.2.7.1.2 Problems

The following problems were observed with most window types:

- Inadequate or no drip on the underside of the sill, allowing water to drain into the wall.

- No seal between windows when joined together, either side by side or one on top of another.

- Same sections used for jambs, heads & sills (in cases where windows are installed without head flashings, the groove that provides a drip on the sill creates a gutter at the head).

- Brick mold and thicker extruded aluminum flanges are rigid enough to press a sealing material against the sheathing, but vinyl and thin aluminum flanges bow out between fasteners. Although the flange is often the only part of the window fastened to the wall, it generally seems unlikely to sustain full design wind loads.

- Curved window heads are difficult to flash.

- Many windows do not use rainscreen design, and have no provisions for drainage of the glazing rebate to the exterior.

4.2.7.1.3 Recommendations

Use head flashings except in very sheltered locations. Specifically, delete the exception allowed by 9.27.3.2.4 of the ABC (see Ref. 19). It is not advantageous to seal the flange at the window head to the sheathing with caulking instead of installing a flashing because:

- sealant may gradually work or "pump" out of the joint due to thermal movement,
- the top of the sealant bead will trap water if it is below the top edge of the flange and uneven,
- flanges of vinyl windows and some aluminum windows are not stiff enough to maintain a seal between fasteners, and
- compatibility of sealant with vinyl may be a problem.

Select windows which are designed based on the rainscreen principle, with provisions for drainage of the glazing rebate to the exterior.

Select windows that project beyond the face of the cladding a minimum of 10 mm and have an effective drip on the underside of the sill. For retrofits, devise an aluminum or vinyl add-on to form an effective drip if the window framing does not provide one.

Select windows with sufficient rigidity to prevent significant rotation of frames under wind loads.

Select windows with weep holes (10 mm minimum diameter to prevent blockage and bridging by surface tension) and sloped drainage, allowing penetrating water to weep out of glazing and sash rebates.

Air seal joints of extensions of the window frame to the interior (jamb and head liners, and window sills) with fasteners and sealant. Seal casings, so that the interior finish, extensions to the window frame, and the frame itself form an airtight assembly (refer to Detail 13 ADA of the Best Practice Guide: Wood-Frame Envelopes in the Coastal Climate of British Columbia (see Ref. 21)).

Select windows with continuous flange corners, sealed or fused.

Seal joints between adjacent windows, and provide mullions designed to carry wind loads.

Provide curved head flashings with curved window heads.

Expand the provisions of CSA A440 to include testing of complete assemblies and perimeter seals to common adjacent materials.

Ensure door perimeter details are sealed using similar procedures to window perimeters.

4.2.7.2 Vinyl Windows & Doors

4.2.7.2.1 Properties

Vinyl formulations typically have high coefficients of thermal expansion. No information was obtained on specific materials used for windows, but Handegord (see Ref. 3) gives a range of values for vinyl in general of 42 to 72 x 10^{-6} mm/mm/°C. Assuming a sol-air temperature 41°C above temperature at time of installation, a two metre vinyl window will expand 3.5 to 6 mm, while the opening in stucco cladding would only expand 1 mm. For comparison, the coefficients of other relevant materials are listed in Table 18.

Table 18: Coefficients of Thermal Expansion

Material	Coefficient (x 10^{-6} mm/mm/°C)
Vinyl	42 - 72
Aluminum	23
Stucco	12
Glass	9
Wood, Parallel to Grain	4

Since PVC's also have a low modulus of elasticity, buckling of vinyl window frames is likely if cladding such as stucco is installed tightly against them. This was observed at a few buildings reviewed.

Depending on plasticizers and temperature, vinyls can be brittle, and they have low strength compared to other window frame materials. Flanges on vinyl windows are more likely to be broken during installation than other flange types which usually bend and can be fixed if they are damaged.

The designs used for vinyl windows are more likely to provide drainage for the glazing rebate than designs of other types. Because the corners are welded, vinyl windows rarely leak at corners or through the frame, however junctions with glass and the sash are prone to leakage due to differential movement and flexing.

4.2.7.2.2 Problems

The following problems were observed with vinyl windows:

- the flanges are too flexible, and often dimple at fasteners,
- flanges break easily during handling and installation, particularly when cold,
- non-reinforced mullions are often too flexible (it seems very unlikely that some of the multiple windows observed will remain in place if they are ever exposed to the 1/10 design wind pressure),
- stucco restrains thermal expansion and sometimes causes buckling of the frames, and
- seals between the sash and frame and between the sash and glazing are often not tight due to flexibility of members (condensation was observed dripping out of drainage slots onto the wall in one instance).

4.2.7.2.3 Recommendations

Reinforce frames and flanges. Verify that as assembled and installed, windows and assemblies of multiple windows can withstand design wind loads. Use continuous reinforcement from jamb to jamb, or from head to sill, designed to carry wind loads, when windows are stacked or placed side-by-side.

Leave a gap between stucco and vinyl windows, sealed with a compatible low-modulus sealant, and sized to accommodate thermal expansion of the window. As a better alternative, provide baffled joints between frames and cladding using frame extensions that will keep water out without being sealed, and that also accommodate thermal movement.

Design gaskets, seals, flanges and attachments to accommodate thermal cycling.

4.2.7.3 Metal Clad Windows & Doors

Aluminum expands and contracts more than wood or glass, but less than vinyl. In the case described for vinyl windows, an aluminum frame would expand 2 mm instead of 3.5 to 6 mm for vinyl. Limited spalling of stucco perimeters was observed, likely due to shrinkage and cracking of the stucco.

Mitred corner joints of metal-cladding are difficult to seal permanently, and therefore there is a greater potential for water leakage through the frame.

4.2.7.3.1 Recommendations

Ensure window corner junctions are adequately sealed. Waterproof the sill rough opening to prevent leakage into the wall.

4.2.7.4 Wood

Wood windows are uncommon in new construction, at least in the sample. Issues and recommendations are similar to those for metal clad windows. Thermal expansion and contraction are not as likely to be problems, however the potential for absorption of moisture and maintenance can be greater than vinyl or aluminum windows.

4.2.8 WINDOW & DOOR INSTALLATION

4.2.8.1 Current Practices

Windows and doors are installed by framers, not window installation specialists.

Typically a 150 - 200 mm wide strip of building paper is installed on the sheathing around the window openings, folded over at corners to speed and simplify installation. When covered over by the sheathing membrane on the wall, the folds create troughs that collect water. Less frequently, housewrap is used around openings, although building paper is used over the remainder of the wall. In some installations there was no sheathing paper strip around the openings.

After the windows are installed, the building paper is lapped over the flanges and over the paper strip, if present, on all sides. This is appropriate at head and jambs, but at the sill the lap leads water behind the building paper, and into the wall.

In some cases, flanges are taped or caulked to the paper or housewrap strip with a corner bead along the edge.

4.2.8.2 Problems

Framers have limited knowledge of window performance, need training on installation practices, and don't know about special installation or handling requirements, particularly with large windows.

Head flashings are frequently omitted, and when installed have inadequate slopes and drips.

The sheathing membrane at the sill almost always laps over the flange, so that water that reaches this juncture is directed into, not out of the wall.

There is typically no seal between the door threshold and the rough opening. This was true on 49 of the 50 buildings in the study. Basement window sills and jambs are similar to door thresholds, with no secondary barrier to water penetration.

4.2.8.3 Recommendations From The Literature

Typical window manufacturer's installation instructions related to rain penetration are limited, recommending to:

- wrap sheathing membrane around window opening with head overlapping jambs and jambs overlapping sill,
- apply a caulking bead to the nailing flange prior to installing the window, and
- fasten a head flashing above the window fin.

Details on pages 6-88 and 6-89 of the Best Practice Guide: Wood-Frame Envelopes in the Coastal Climate of British Columbia (see Ref. 21), show an effective method of sealing window perimeters using a 3/4D Build Detail. The details are based on the use of a vented and drained cavity behind the cladding, recommended for exposed locations. The details account for the possibility of leakage through the window corners to be drained to the exterior. Shims behind the flange with gaps between them, or drain holes installed through the flange, are required to allow for drainage. The detail requires a sealant compatible with, and that will adhere to the waterproof membrane used.

4.2.8.4 Recommendations for Retrofits

Remove enough cladding to allow proper flashing around the entire opening, including the sill, and to permit paper above to lap over the repair.

Install peel-and-stick membrane sealed to the sheathing 50 mm minimum, and to the head and jamb flanges of the window. Install the peel-and-stick membrane under the sheathing membrane and behind the head flashing. Lap the sheathing membrane over the head flashing. Where possible, install the sheathing membrane lapped under the sill flange. If the joint between the flange and the sheathing is too tight to permit this, seal this flange with peel-and-stick as well. Bear in mind that repairs to the perimeter will not repair leaks through the window frame itself into the wall, if they exist, and may make the problem worse. If window leakage into the wall cannot be accommodated, remove the window, assess damage to the sill of the rough opening, and reinstall with a drained flashing on the sill and lower parts of the jambs of the rough opening (see recommended method of installation for severe exposures below).

Instead of trying to match colour and texture of existing stucco in the same plane, introduce a change of plane and perhaps colour in the repair detail.

4.2.8.5 Recommendations for New Construction

Have window installations completed by glazers who deliver the windows to site. This will result in less theft (no on-site storage waiting for installation), less damage due to handling, and better installation by knowledgeable personnel aware of special requirements, with compatible caulking, flashing membranes, and other specialized materials and tools required for difficult installations.

For the most severe Alberta exposures, like windows on upper stories of multi-storey buildings and houses on West or North-facing ridges with minimal shielding, Details similar to 11ADA - Window Head, 12ADA - Window Jamb, and 13ADA - Window Sill, from the Best Practice Guide: Wood-Frame Envelope in the Coastal Climate of British Columbia (see Ref. 21) are recommended. These details include a rainscreen stucco cladding assembly, with a drained and vented cavity. Other cladding can also be used, but the drained and vented cavity should be retained. (The installation of a polyethylene vapour barrier to the interior wall is recommended for Alberta construction). The plane of the interior gypsum board should be air tight.

For less exposed locations, the peel-and-stick membrane seal may be deleted from the head and jamb sections, except for the bottom 150 mm of each jamb. Install membrane to the sill rough opening similar to the procedure for severe exposures above. In addition, deleting the drained cavity behind the cladding will reduce costs.

In all the cases considered above, the cavity between the window frame and rough opening must be sealed to the gypsum board air barrier (from the window frame to the interior gypsum board, including sills and jamb linings), so that the space is air sealed to the interior, and vented and drained to the exterior at the sill.

For normal exposures, and only where the risk of leakage through joints in the corners of the window frames is acceptably low, install windows (and doors) as indicated in the Alberta New Home Warranty Better Building Tips "Prevention of Water Penetration around Openings" (see Ref. 10). The "Tips" do not specify what paper to use for the flashing: consider using a high quality sheathing membrane, not regular building paper, around the perimeters of windows and doors, or use a peel-and-stick membrane to seal the flanges to the sheathing. Ensure that the sheathing membrane is correctly lapped, particularly at the sill. The same details are illustrated with more clarity, in FWB1, 2, and 3 in the Stucco Resource Guide (except that they do not mention sealing the window flange to the sheathing

membrane (see Ref. 9)).

It is still important to ensure that the airspace between the window frame and the rough opening is sealed more tightly to the gypsum board than at the exterior, to ensure that air pressure differences that might drive water into it past the seals of the flanges are minimized, even though drainage to the exterior is no longer provided.

At heads of curved windows use peel-and-stick membrane in all cases if the windows have discontinuous flanges. Extend the edge of the membrane onto the casing, so the notches in the flange are covered. If the head flashing is also notched, do the same with it before installing the sheathing membrane.

The method recommended for normal exposures should not be used for more severe exposures because all approaches that seal flanges to the wall suffer from an Achilles heel: if the window frame leaks into the wall the water cannot escape except by evaporation. Few instances were seen where joints in the window frame had leaked into the wall assembly. However, this window installation procedure does not provide waterproofing of the window sill section, or provide for drainage to the exterior in the event of leakage from joints in the window frame. The installation of a peel-and stick membrane to the sill of the rough opening prior to the installation of the window, with provisions for venting and drainage of the spaces between the window frame and the rough opening, protects the wall in the event of window leakage, and also deals with leakage through joints between flanges and paper flashings. It is best if this secondary flashing slopes to the exterior, with an upstand at the interior face, rather than being level with an add-on upstand over the membrane.

4.2.9 BALCONY CONNECTIONS

4.2.9.1 Properties

Vinyl sheet waterproofing is almost universal for balconies, and was also used on the few decks observed.

The material itself and adhesives used to install it are reasonably durable, under light foot traffic, but detailing at edges, joints, corners, and scuppers is critical.

4.2.9.2 Problems

Vinyl deck covering is typically installed after the cladding is complete, into an unclad recess left by the previous trades. Water draining off the surface of the wall cladding, and water draining down behind the wall cladding, can get behind the vinyl deck flashing because a shingled lap is rarely provided.

In some cases observed, metal edge flashings at the outside deck edge had been glued over the vinyl with sealant. This flashing formed a dam at the edge, and water ran under the metal through imperfections in the seal and into the structure behind the flashing.

Vinyl membrane is easily punctured, and therefore should not be used over occupied interior spaces. It must be installed after the cladding is completed, if damage during construction is to be avoided.

4.2.9.3 Recommendations

CCMC approvals for decking include details which require that the upper edge of the deck covering be terminated under the shelter of a flashing that intercepts water running down the surface of the wall, and water draining down the surface of the sheathing membrane, so that it cannot get behind the vinyl.

Builders prefer to install the deck waterproofing after the cladding to minimize damage. In some cases, the entire deck is an option for future construction by the homeowner, with minimum necessary provisions built in beforehand.

Use a detail similar to Figure 3 on page 840 of the current CCMC Registry (see Ref. 5). Drainage of moisture from the wall is provided out onto the deck. The detail allows the deck surface to be installed after the wall above it is complete, and makes deck replacement possible without removal of cladding. The metal flashing should overlap the edge of the deck membrane flashing by 75 mm, the horizontal surfaces should slope to drain, and the upper leg of the metal flashing should extend behind the sheathing membrane a minimum of 100 mm.

For exterior edges, Figure 4 on page 841 of the CCMC Registry provides a satisfactory detail. Scuppers off decks should be detailed similarly, with a greater clearance between the drip and the wall below. They should be sized 150 mm wide and 100 mm high, or larger, for hand clearance during installation even if the watershed area is small. For both edges and scuppers, water must always run on a vinyl surface all the way to the drip. If water runs over a vinyl edge onto metal or

some other material, even if the vinyl is lapped over the other material and glued to it, water will eventually be drawn by surface tension into joint imperfections.

Joints at corners in vinyl deck flashings are a critical detail that must be sealed to avoid leakage from the deck into the wall. Houses with decks often have no inside corners against the house, or have only one, but with more complicated buildings these joints are more numerous. They should be lapped and glued, not butted and covered with sealant.

4.2.10 SMALL PENETRATIONS

4.2.10.1 Properties

Small penetrations such as hose bibs, vents, electrical boxes, and utility lines are generally not flashed. The factory-made pieces often have flanges which are evidently intended to be face-sealed to the cladding surface.

Penetrations like dryer vents are often made of non-durable materials. They are not expensive to replace if broken or worn out, so this is reasonable, but not if cladding has to be removed to do it.

4.2.10.2 Problems

Small penetrations are usually installed before the cladding is applied, so the flanges get embedded in stucco or behind other cladding.

The flanges are often installed after the sheathing membrane is installed so that water draining behind the back of the cladding runs behind the flange and is more likely to go inside the wall than outside or around the penetration.

If penetrations are installed after the cladding, there is no seal at the plane of the sheathing membrane, and the same problem with water running behind the flange occurs at the surface.

Through-wall combustion vents are usually installed horizontally, which means in practice that half of them slope back into the wall (assuming that errors fall equally on both sides of the intended position). Significant moisture damage was observed on sample buildings in cases where condensation ran back into the wall, on both the interior and exterior surfaces of a vent pipe. Although no instances of damage were observed, note that many gas fireplace vents are installed under overhangs.

This could result in damage from condensation of moisture from the flue on the underside of the overhang, or inside the structure if there are vents in the overhang, in cold weather.

There was little leakage at penetrations, despite these deficiencies, probably because they often occur in sheltered locations, and also because the area of the wall that sheds water onto most penetrations is small. However, in exposed locations they can admit substantial amounts of water into the wall.

4.2.10.3 Recommendations

Install penetrations so that they can be replaced without disturbing the cladding. Sealing a flange to the face of the cladding is acceptable if the penetration is in a sheltered location (under a bay window or under a waterproofed deck, for instance). Greater care should be taken in exposed locations.

Design flashings for penetration details so the penetrating elements can be replaced if damaged without removal of cladding, and so that water draining down cladding and sheathing membrane surfaces are kept away from the penetration.

4.2.11 FOUNDATIONS

Foundations are generally outside the scope of this study, but the way the wall above interfaces with the top of the foundation sometimes results in moisture problems.

4.2.11.1 Problems

Stucco carried down onto the foundation and adhered to the concrete, traps any moisture behind the stucco and directs it inward.

If sheathing membrane and cladding stop right at the bottom of the rim joist, they leave an open and exposed joint between the frame wall and the top of the basement wall. In an exposed location, much of the water draining down a wall will enter this joint. The ladder or rim joist junction with the concrete is not watertight.

4.2.11.2 Recommendations

Terminate the sheathing membrane and cladding at least 50 mm below the top of the foundation wall.

Provide a flashing at the bottom of the cladding, with the sheathing membrane lapped over the vertical leg of the flashing, so that water will drip free onto the ground rather than run down the face of the foundation wall.

4.2.12 AIR LEAKAGE

In the Alberta climate, particularly in midwinter, humidity in indoor air creates a potential for condensation in the walls. Very low rates of air leakage must be achieved if the interior is humidified, to avoid excessive condensation and resulting moisture damage.

The location of the plane of greatest resistance to air flow through a wall determines where the greatest air pressure change exists when indoor and outdoor pressures are unequal. If this plane is the same one that is keeping water out of the building, then air pressure differences, and air movement both help to transport water into the wall on the windward side.

4.2.12.1 Problems

Occupants who are determined to have high humidity indoors in winter are almost certain to have condensation problems. Condensation is not a bigger problem in Alberta only because most people are resigned to low humidity in midwinter.

Although it is difficult to be sure (assessments of the most airtight plane were made without benefit of pressure measurements in the stud space) it is likely that water leakage problems are made worse when the water shedding surfaces of the wall are also the most airtight as they are in many cases, particularly with stucco. If viewed from the exterior of the building, the pressure difference over the wetted surface would appear to pull water into the wall during wind-driven rains.

4.2.12.2 Recommendations for Retrofit

Make the inside surface of the wall as airtight as possible. Look carefully for indirect paths of air leakage from the interior to the back of the sheathing. The largest and most severe air leaks are likely to be around chimneys, and between joists extending from heated spaces to ceilings of unheated spaces (like garages or cantilevered floors). Other common locations are window and door perimeters, rim joists, pot lights and electrical outlets. Reduction of air leakage will reduce interstitial condensation if the indoor air contains humidity in excess of saturation for the outdoor temperature in winter. Making the interior gypsum board the most airtight surface in the wall will reduce wind-driven rain penetration by separating the air barrier from the weather barrier.

In typical Alberta houses, if condensation appears on windows, an indication that it is also occurring unseen in walls, indoor humidity should be reduced to minimize damage.

4.2.12.3 Recommendations for New Construction

For walls clad with stucco, unless a vented airspace and drainage layer are provided between the stucco and the sheathing, make the interior gypsum board plane more airtight than any other layer of the wall, so that the pressure difference between the exterior and the stud space will be minimized and therefore reduce the amount of water moving through defects in the sheathing membrane and flashings, particularly at perimeters of openings (also referred to as the Airtight Drywall Approach to sealing). Taping or other means of sealing joints in the sheathing membrane are therefore not recommended. Most of the problems observed in the study were due to the combination of wind and rain. If the air pressure difference across a film of water bridging a defect on the exterior can be eliminated, the effect of wind is reduced. This may be very difficult, since stucco tends to be relatively airtight. Testing of the effectiveness of interior sealing measures is advisable.

The airtightness of the wall can be improved considerably if the air barrier is made continuous past intersecting walls, stair stringers, floor plates, and behind bathtubs, and if indoor electrical outlets are located whenever possible on interior partitions rather than in the exterior wall.

Where water problems were traced back to condensation from indoor air, air movement was always the prime mover of moisture, transporting indoor air through penetrations on the inside so that it reached surfaces on the cold side. Problems were observed where indoor humidity was the source, but there were no cases where diffusion in the absence of air movement appeared to be the cause.

4.2.13 DRAINAGE

In several cases, walls were exposed to unusual amounts of water because of inadequate drainage of roofs and decks. Gutters and downspouts should be sized larger than the code requires for the area drained, particularly where scuppers are used, or where multiple elbows and changes in direction increase resistance to flow. Scuppers need to project at least 50 - 75 mm, depending on the area served, if they are not connected to downspouts, to ensure that water spills free of the wall below.

4.2.14 SUMMARY OF RECOMMENDATIONS

The most important precaution to avoid water penetration of walls is to assess the exposure of each particular wall in terms of overhangs, predominant winds, surroundings, and height above ground, and use details appropriate for the expected conditions. To apply precautions adequate for the most severe exposures to all cases would be expensive, however may be acceptable to some home owners or contractors for the added security.

For severe exposures, use details similar to those recommended in the B.C. Coastal Best Practice Guide (see Ref. 21), based on the Airtight Drywall Approach (ADA) with the addition of an interior Type 1 vapour barrier. Use the gypsum board as the air barrier. Air seal joints of extensions of the window frame to the interior (jamb and head liners, and window sills) with fasteners and sealant. Seal casing, so that the interior finish, extensions to the window frame, and the frame itself form an airtight assembly. Details 11ADA, 12ADA, and 13 ADA have been discussed. Other ADA details in from the Guide should also be used, with modifications for various exposures. The most important feature of these details is the pressure-moderated, drained air space behind the cladding.

For typical construction and normal exposures, correctly lapped sheathing membrane around penetrations may provide an acceptable level of performance.

Sheathing Membranes

Continue to use the same sheathing membrane materials (building paper and housewrap), with some changes to common practice. Using more water resistant membranes will not solve the problems with the way the material is applied, and will reduce drying rates.

- Always lap joints like shingles, to shed water. Use tape sparingly, and only as a means of temporary securement. Make sure that windows and similar penetrating elements lap over the sheathing membrane at the sill.

- Use two layers when building paper will be exposed to the weather for more than 30 days, applied with laps offset between layers.

- Make sure that neither the cladding, nor the sheathing membrane, is the most airtight layer in the wall.

Peel-and-stick Membranes

Where peel-and-stick membranes are used, verify that the surfaces they will contact are compatible and follow manufacturer's recommendations for surface preparation, conditioning, and priming.

Vinyl Siding

Install vinyl siding and accessories so that they will function, as much as possible, as a rainscreen system. Use drip flashings at heads of openings, with J-mold trim if required to hide cut edges of siding, perforated above the flashing to prevent it acting as a gutter. Install sill flashings with drips at sills of all openings.

Stucco

Mix stucco using only materials listed in the ABC, with additional materials, if any, that do not impair the strength, imperviousness, water repellency, or frost resistance of the cured material. Most additives now used make installation easier, but substantially degrade the finished product. In addition consider the following:

- Use accessories with enough depth that stucco will have the minimum thickness required by the ABC when they are used as grounds. Apply the correct minimum thickness.

- Mist stucco to prevent drying and excessive cracking during initial curing.

- Avoid horizontal surfaces, unless they are protected by flashings. Limit unprotected projections to ledges not more than 50 mm wide, sloped not less than 45 degrees.

- Use 2 layers of building paper as sheathing membrane under stucco, unless there is a drained and vented cavity behind the cladding.

- Use flashings at all horizontal joints, with the vertical leg extending up behind the sheathing membrane, and a drip leg to shelter the top edge of the stucco below the joint. Make horizontal joints continuous past vertical joints (if there are any). Avoid joints when they are not needed (compare expected shrinkage of stucco and framing).

- Provide joints, caulked or baffled, to provide for movement of frames at openings, particularly when vinyl frames are used.

Flashings

For normal exposures, use flashings with at least 50 mm vertical legs (as required by the ABC). For more severe exposures, use flashings with 100 mm legs extending behind the sheathing membrane. Slope all horizontal surfaces of flashings a minimum of 30 degrees, to drain outward. Provide flashing end dams. Use flashings with enough projection (6 mm or more beyond the vertical face behind the drip) that drops of water on the drip edge will fall free, rather than cling to the surface behind the flashing. Avoid lap joints in flashings where possible, and seal them when they cannot be avoided.

Windows and Doors

For severe exposures, use the B.C. Best Practice Guide details. For moderate exposures, and frame types that might leak at the joints, use peel-and-stick membrane to flash and drain the sill of the rough opening, and to protect the bottom 150 mm of the rough opening jamb from water at the sill. Pressure-equalize the cavity between the window frame and the rough opening to the exterior.

Seal the flanges of frames to paper flashings applied around openings beforehand only for normal and sheltered exposures. Conform to the Alberta New Home Warranty "Tips" and consider using a high quality flashing paper instead of regular building paper or housewrap for the flashings. Alternatively, apply strips of peel-and-stick membrane over the flanges after the frames are installed (and before the sheathing membrane). Ensure that sill flanges will drain onto the exterior face of the sheathing membrane, not behind it.

Use head flashings except in very sheltered locations, despite exceptions allowed by Code. Make head flashings for curved windows continuous.

Select windows designed based on rainscreen principles, and that allow water that gets into glazing rebates or joints to drain to the exterior.

Design window arrays (not just the individual windows) to support the factored wind loads prescribed by the ABC. Ensure the complete window assembly meets the CSA A440 requirements.

Provide effective drips at sills, either by selecting frames with adequate projection and a drip, or by adding a supplementary flashing.

Select windows with continuity of the flanges at corners.

Seal large windows constructed using arrays of smaller windows to each other, and provide pressure equalization and drainage of the joint between frames. Seal window frames to the interior air barrier.

Employ glaziers, rather than framers, to install windows. Install windows immediately upon delivery to the site.

Balconies

Use flashings where balconies and decks adjoin walls that allow for installation of vinyl deck covering after all other work is completed, as well as for future replacement of the vinyl without disruption of the cladding. Extend flashings up 100 mm behind the sheathing membrane, so that water draining down inside the wall on the membrane surface will drain out onto the deck, rather than by-pass it.

Take particular care to seal joints in the vinyl at inside corners where three surfaces (deck and two walls) join. Butt joints covered with sealant are not satisfactory to provide a durable means of waterproofing.

Extend the vinyl membrane all the way to the drip edge at open edges and in scuppers.

Small Penetrations

Install small penetrations with flashings at the head and sill similar to flashings for larger openings, unless they are in very sheltered locations (in that case, seal the flange of the penetration to the face of the cladding). Install small penetrations so that non-durable items can be replaced in the future without disrupting the cladding.

Foundations

Extend the sheathing membrane and cladding a minimum of 50 mm below the joint between the floor framing and concrete foundation. Provide a drip flashing that will intercept water draining down the surface of the sheathing membrane and allow it to drip free of the foundation below it.

Air Leakage

Ensure that the interior finish is the most airtight layer of the wall. Avoid face-seal methods of keeping air and water from penetrating the exterior wall face. Ensure that when condensation does occur, it can drain and or dry to the exterior rather than being trapped in the wall, and that water leaking into the wall under extreme conditions can escape the same way.

Drainage

Ensure that drainage from horizontal surfaces (roofs and decks) does not impinge on wall surfaces. Gutters, downspouts, and scuppers that are sized to the minimum requirements of the code may overflow or freeze up from time to time, and create a hazard if they discharge onto wall surfaces. Increased sizes and heat tracing should be considered where this possibility exists.

Yours truly,
BUILDING ENVELOPE ENGINEERING INC.

Anton J. Vlooswyk, P.Eng.

John A. Vlooswyk, P.Eng.

James B. Posey

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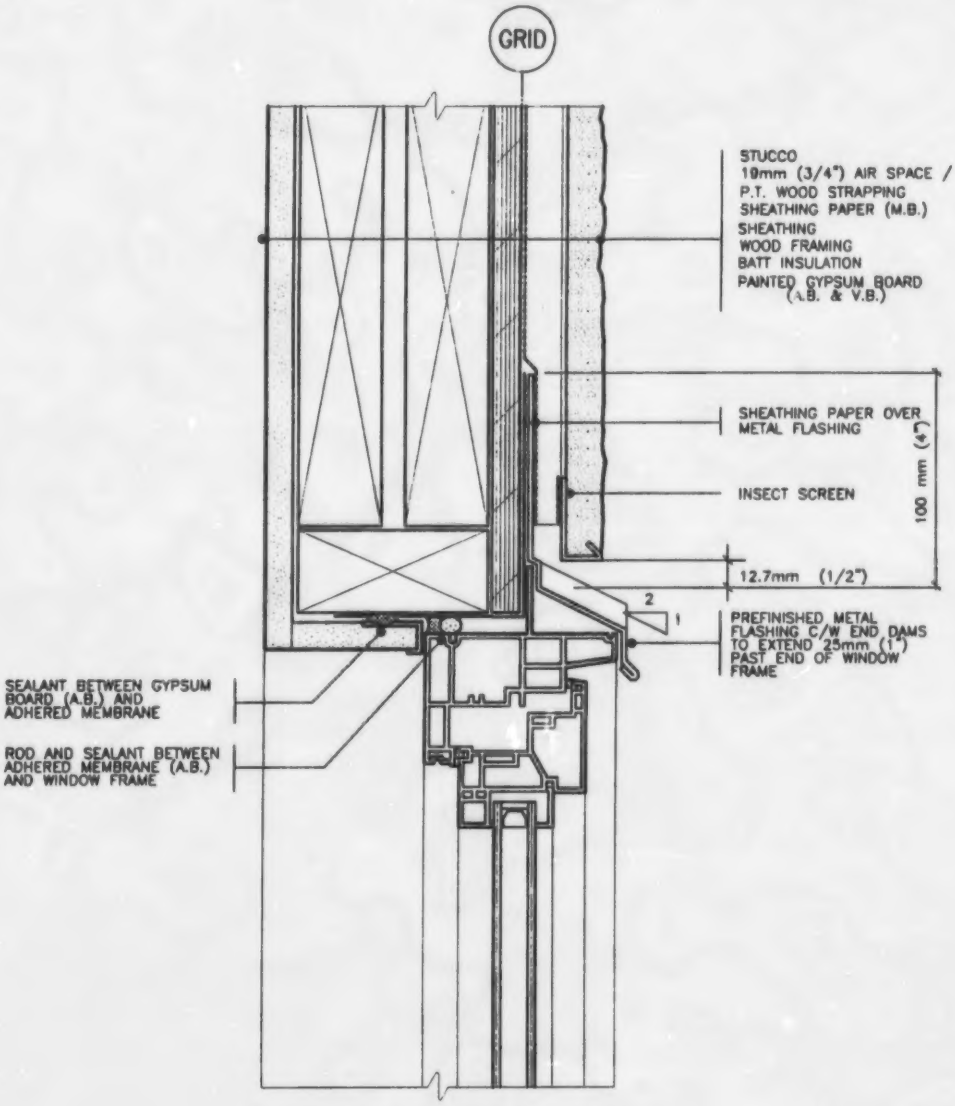
Appendix A - Illustrations


GRID
STUCCO
19mm (3/4") AIR SPACE / P.T. WOOD STRAPPING
SHEATHING PAPER (M.B.)
SHEATHING
WOOD FRAMING
BATT INSULATION
PAINTED GYPSUM BOARD (A.B. & V.B.)
SHEATHING PAPER OVER METAL FLASHING
INSECT SCREEN
100 mm (4")
12.7mm (1/2")
2
1
PREFINISHED METAL FLASHING C/W END DAMS TO EXTEND 25mm (1") PAST END OF WINDOW FRAME
SEALANT BETWEEN GYPSUM BOARD (A.B.) AND ADHERED MEMBRANE
ROD AND SEALANT BETWEEN ADHERED MEMBRANE (A.B.) AND WINDOW FRAME

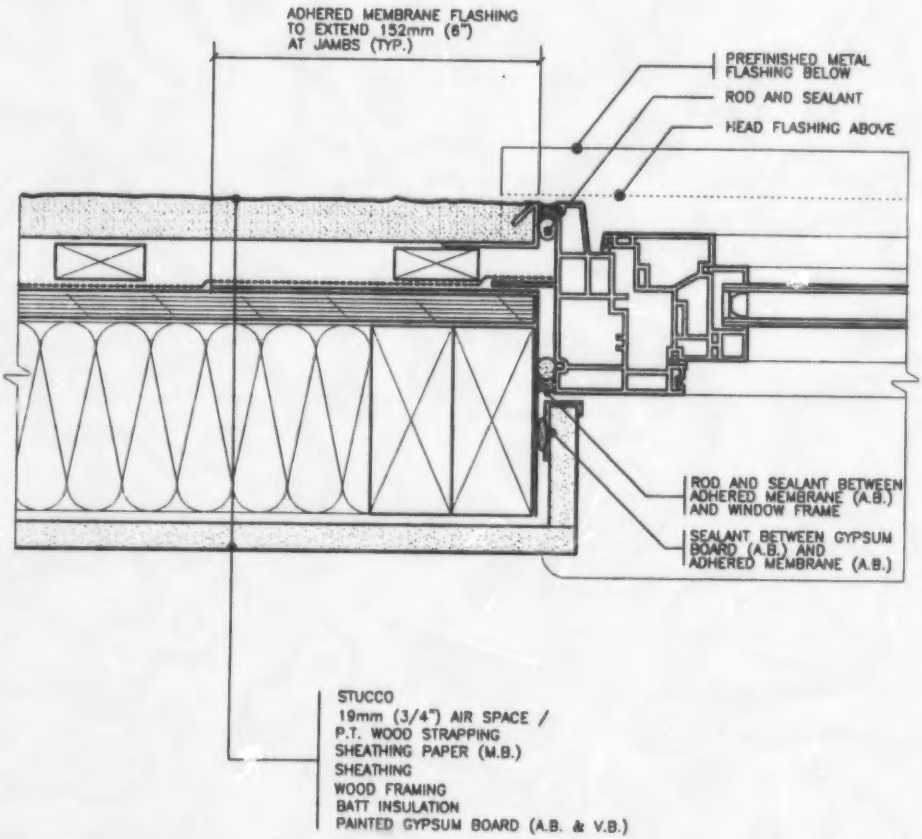
WINDOW HEAD 11ADA

AIRTIGHT DRYWALL APPROACH

1" 0 4" 8"

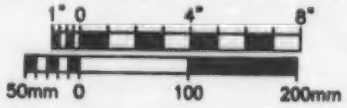
50mm 0 100 200mm

Detail 11 ADA: Window Head–Airtight Drywall Approach

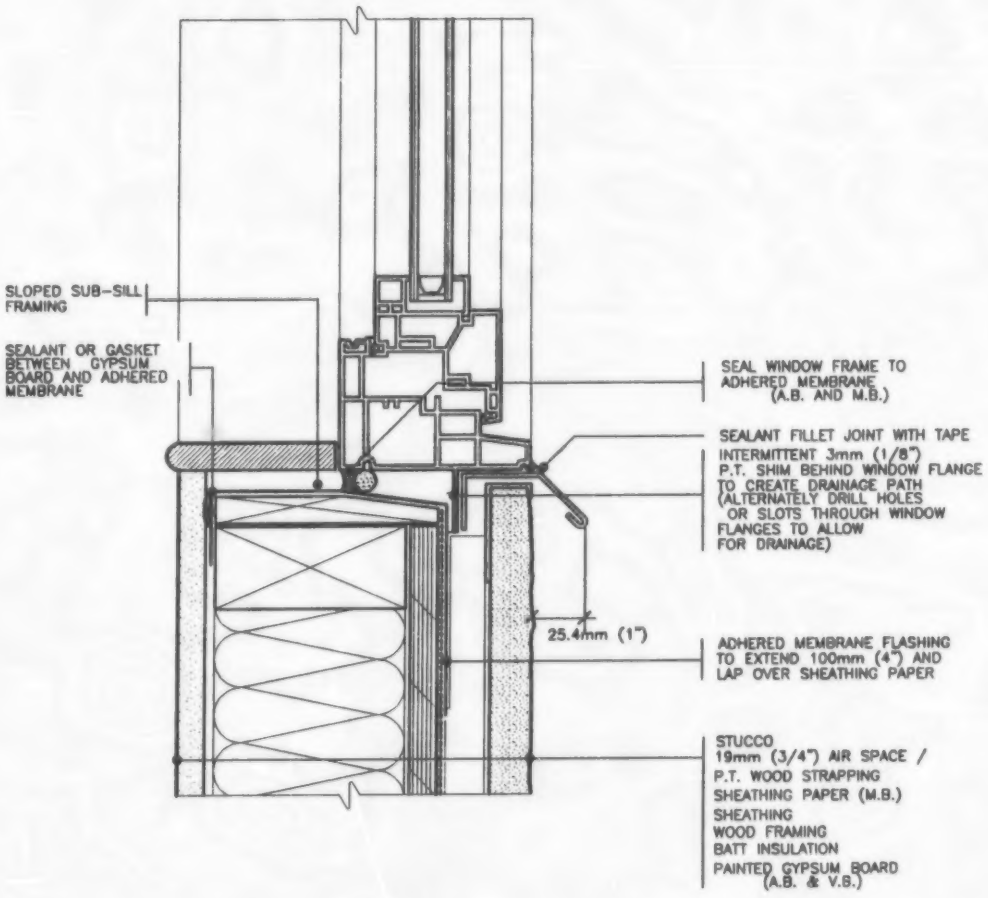


WINDOW JAMB 12ADA

AIRTIGHT DRYWALL APPROACH



Detail 12 ADA: Window Jamb–Airtight Drywall Approach


SLOPED SUB-SILL FRAMING
SEALANT OR GASKET BETWEEN GYPSUM BOARD AND ADHERED MEMBRANE
SEAL WINDOW FRAME TO ADHERED MEMBRANE (A.B. AND M.B.)
SEALANT FILLET JOINT WITH TAPE
INTERMITTENT 3mm (1/8") P.T. SHIM BEHIND WINDOW FLANGE TO CREATE DRAINAGE PATH (ALTERNATELY DRILL HOLES OR SLOTS THROUGH WINDOW FLANGES TO ALLOW FOR DRAINAGE)
25.4mm (1")
ADHERED MEMBRANE FLASHING TO EXTEND 100mm (4") AND LAP OVER SHEATHING PAPER
STUCCO
19mm (3/4") AIR SPACE / P.T. WOOD STRAPPING
SHEATHING PAPER (M.B.)
SHEATHING
WOOD FRAMING
BATT INSULATION
PAINTED GYPSUM BOARD (A.B. & V.B.)

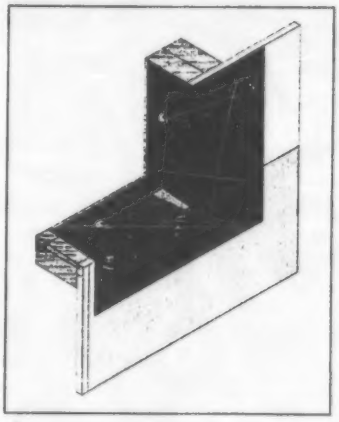
WINDOW SILL — 13ADA

AIRTIGHT DRYWALL APPROACH

1" 0 4" 8"

50mm 0 100 200mm

Detail 13 ADA: Window Sill–Airtight Drywall Approach



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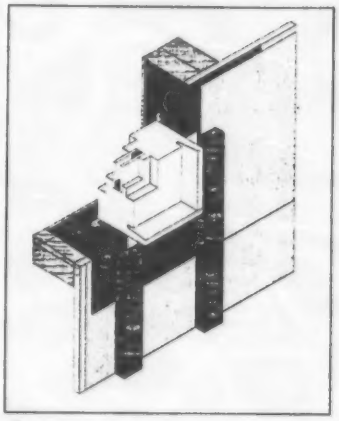

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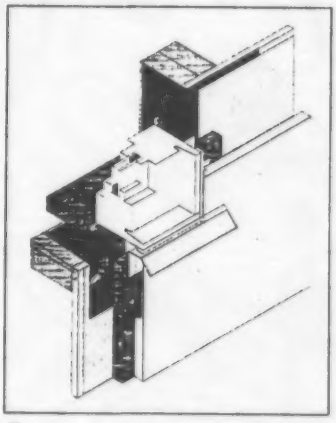

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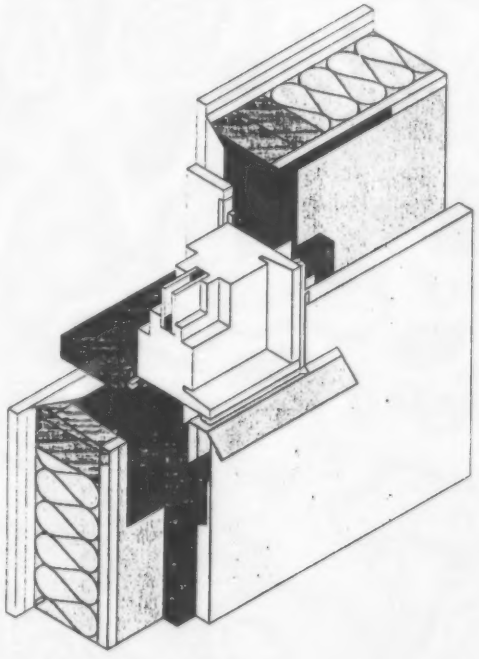


1
- Framing
- Beveled Wood Sub-Sill
- Wall Sheathing
- Sheathing Paper
- Sill Membrane Flashing
- Corner Membrane Flashing
- Jamb Membrane Flashing

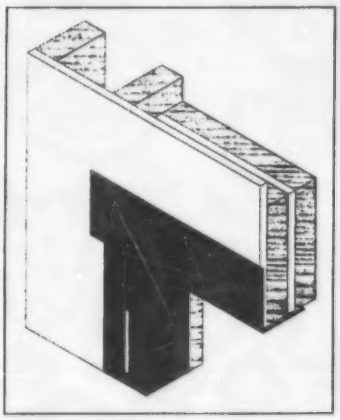
- Wood Shims

2
- Window
- Sheathing Paper
- P.T. Wood Strapping

3
- Metal Drip Edge
- Stucco Cladding (including: Lath, Paper & Accessories)
- Backer Rod & Exterior Caulking

- Backer Rod & Interior Caulking
- Insulation
- Polyethylene
- Window Sill
- Interior Gypsum Board

Window Sill/Jamb



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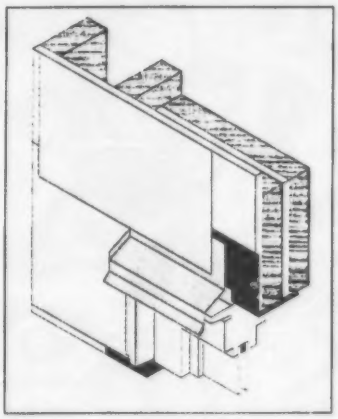

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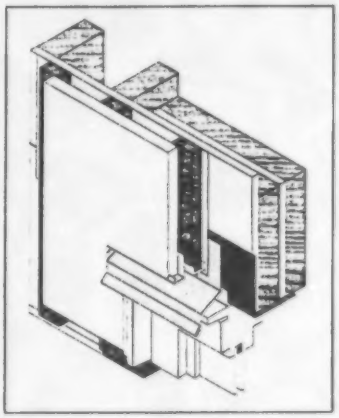

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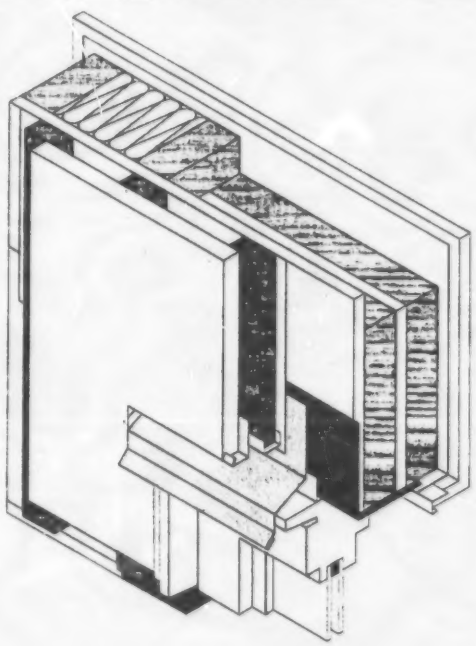


1	Framing
	Wall Sheathing
	Jamb Membrane Flashing
	Head Membrane Flashing
2	Window
	Sheathing Paper
	Metal Head Flashing
	Sheathing Paper
3	P.T. Wood Strapping
	Insect Screen
	Stucco Cladding (including: Lath, Paper & Accessories)
	Backer Rod & Exterior Caulking
	Insulation
	Polyethylene (Sealed to membrane)
	Interior Gypsum Board

Window Head/Jamb

The Alberta New Home Warranty Program
#201, 10335 - 172 Street
Edmonton, Alberta, T5S 1K9

Better Building Tips:

Prevention of Water Penetration Around Openings

Introduction:

Conformance to the following recommended construction details will help to alleviate problems associated with water entry around openings such as windows and doors.

Products:

Sheathing Paper, Flashing, and Caulking: As per Alberta Building Code (1990).

Execution:

Install sill piece first (A); then overlap side pieces (B). Attach beneath area where window will overlap only.

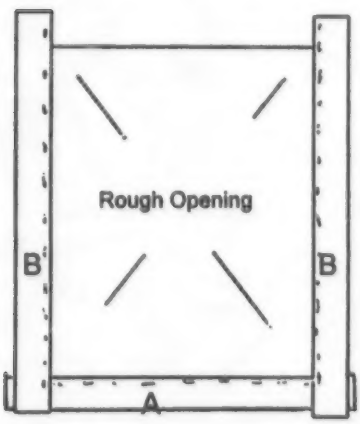


Fig. 1

Apply bead of sealant within 12 mm (½") of opening. (recommended)

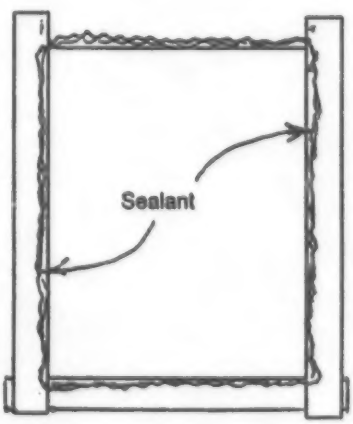


Fig. 2

Install window.

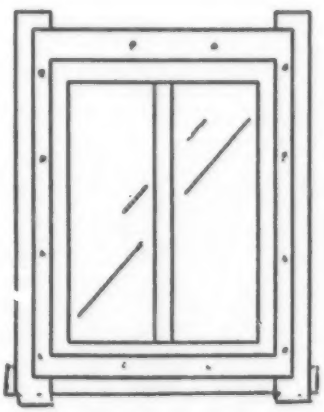
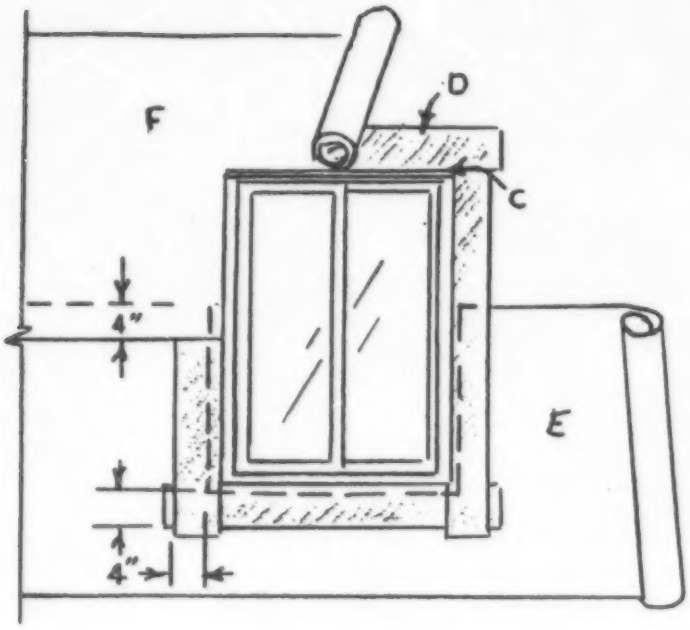


Fig. 3



(C) Install metal flashing (optional as required) across top of frame.

(D) Apply building paper at head, overlapping nailing fin (or drip flashing if installed) and jamb pieces.

(E, F) Apply building paper shingle fashion. Ensure that the piece beneath the window underlies the sill piece and that all laps are at least 100 mm (4") in width.

Fig. 4

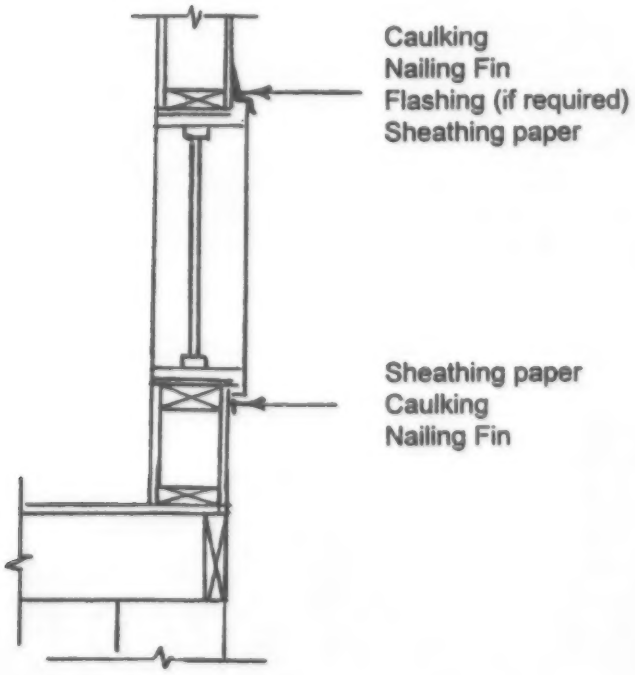


Fig. 5

Appendix B - Glossary

Appendix B - Glossary

Building paper: asphalt impregnated paper conforming to CGSB-51.32-M77.

Housewrap: spunbonded or laminated perforated film synthetic sheathing membrane material.

Peel-and-stick membrane: a sheet material, consisting of a coating of tacky synthetic rubber (usually styrene-butadiene-styrene or SBS) modified asphalt on a carrier sheet (usually polyethylene film) that is adhesive and waterproof.

Sheathing membrane: the secondary weather barrier consisting of asphalt-impregnated paper, spunbonded polyolefin sheet, perforated plastic film on woven or spunbonded fabric, or similar sheet materials applied over the sheathing of a building before furring or finished cladding is applied.

"X" minute building paper: building paper that has a rating of X minutes when tested to ASTM D779-94, where "X" is often 30, but can be more or less.

Appendix C - Data Input Guide and Form

DATA COLLECTION - GENERAL

The data collection for each building consists of the four following general areas:

- General Building Information,
- Wall Assembly Description,
- Symptom Description, and
- Failure Mechanism.

The data collection worksheets are based on those previously prepared for the "Survey of Building Envelope Failures in the Coastal Climate of B.C." for comparative purposes, and modified as required for this study. A copy of the data collection worksheets are attached.

The *General Building Information* and *Wall Assembly Description* worksheets are used to document general information for each building, based on filling in blanks for various predetermined categories and choices. Items that describe the quality of design, material, or installation are marked with "P" for poor, "A" for acceptable, "NK" or "K-NK" for not known, and "NA" or "A-NA" where not applicable. Items assessed as poor are described in the *Description of Problem* section of the *Symptom Description* worksheet, if related to observed problems, and are otherwise described in *General Building Notes* appended to the *General Building Information* worksheet.

For buildings where problems were observed, the *Symptom Description* worksheets are used to document each moisture related problem experienced. The *Failure Mechanism* worksheets are used to classify the design, construction, maintenance, and operation of the building and indicate whether they contributed to the problem noted.

A detailed description of each of the data collection worksheets is provided below.

A. GENERAL BUILDING INFORMATION

General

A *General Building Information* worksheet is filled out for each building. The *Building Identification Number* are recorded on all worksheets related to the building. The *Data Source* indicates whether the information comes from previous investigations or specific investigation for this study. The *Date* is the date the building was investigated unless the information comes from files on an historical investigation. "*Evaluated by ...*" indicates the individuals who saw the building and participated in the field investigation. In "*Constructed for ...*", *Market* indicates that at time of construction, the owner or occupant was unknown, *Occupant* indicates a custom home constructed, if not designed, for a particular buyer, and *Subsidized* indicates for co-op or subsidized housing. *Year Constructed* is the year of substantial completion, or 1999 if still

under construction. *Number of Storeys* is determined in accordance with the Alberta Building Code.

The building name and address are not included as part of the survey form. This information, and the names of window manufacturers, has been recorded separately to ensure confidentiality.

The overall cost of the problem investigation and moisture related repairs are indicated, where reported by either the owner or contractor.

Shielding
The wind shielding information for each building is collected for each elevation, relative to the nearest compass point, based on protection provided by adjacent buildings and landscapes during wind driven rains.

Windows
A single window type is assumed for each building. The manufacturer is numerically recorded, to allow for generic reference to section details. Where more than one sash type is used, the most common sash type is recorded.

The following definitions for windows are provided:

Sealant at Exterior Perimeter: Indicates windows where the frame to cladding joints are sealed with a sealant.

Placement: Assumed *flush* if the exterior pane of the glass is within 25 mm of the plane of the cladding. Where decorative protrusions are installed around the windows, including battens, the window placement was considered relative to the plane of the general wall cladding and not the protrusion, unless the weather barrier as well as the cladding was wrapped around the protrusion. A window is assumed *rebate*, where the exterior pane of the glass is recessed from the exterior face of the cladding by more than 25 mm.

Frame Joints: Indicates the condition of the mitred window frame joint corners. Moisture within the glazing rebate may result in leakage into the wall through unsealed or poorly sealed joints in the frame assembly. Where the window frame joints are observed to be sealed (confirmed through testing), the frame joints are recorded as *Sealed, Good Condition*. Where the frame joints are observed to be sealed but failed and contributing to leakage (confirmed through testing), the frame joints were recorded as *Sealed, Failed*. Otherwise, the frame joints were recorded as either *Not Sealed* or *Not Known*.

Design: Windows which rely on the exterior seals to prevent water penetration, and do not provide a secondary means of drainage, are recorded as "Face Sealed". Windows which provide a secondary means of drainage of the glazing cavity, but do not have an interior air seal are recorded as "Drained". Windows with an interior air seal and drained glazing cavity are recorded as "Rainscreen".

Flange: Indicates the method of window attachment to the sheathing material at the perimeters.

B. WALL ASSEMBLY DESCRIPTION

A *Wall Assembly Description* and *Wall Details* worksheet is completed for each typical wall section. Only wood framed walls above grade were reviewed. Wall types, numbered consecutively, are assigned to each *Building Identification Number*. The majority of buildings contain only one wall type, while others may contain two depending mostly on the number of exterior cladding types.

The wall section is documented from the exterior to interior, with layer one at the exterior. Where applicable and known, the thickness is recorded. Opinion as to the component material and installation quality are indicated as either poor, acceptable, or not known. For example, a building with poor stucco mix proportions resulting in a high sand content would be considered poor material quality, while a building with a large number of cracks in the stucco due to insufficient thickness would be considered poor installation quality.

The *Percentage of Building Wall Surface* for each wall type is determined as the total area of the wall surface, relative to the total wall area of the building (including windows and doors).

The most air tight layer of the wall assembly is the layer estimated to have the greatest actual resistance to air flow, not necessarily that indicated by the drawings or intended during construction. Generally, homes with stucco installed as the exterior cladding, the stucco and building paper are assumed to provide the most significant level of air tightness across the wall. Homes with vinyl or aluminum siding installed as the exterior cladding, the interior gypsum board is assumed the most air tight element in the wall assembly. The *Level of Air Tightness* is determined for each wall type, rated on a scale of one to five, with five being the most air tight. For example, most current residential buildings would be considered a three (average). Ratings of four would require significant improvements to air tightness, such as air sealing penetrations through the gypsum board and perimeters with a sealant. A wall section with an air seal membrane and exterior insulation installed would be rated a five.

The layer farthest into the wall assembly to which water entry is acceptable by design, is the sheathing paper for most applications.

C. WALL DETAILS

The *Wall Details* worksheet provides a listing of the various details, penetrations and provisions for drainage and venting for each wall type. The design, material and installation quality for each detail was indicated as either poor, acceptable, not known, or not applicable.

Definitions and design criteria for the wall details are provided below. The material quality of the detail is determined based on the overall durability of the assembly, while the installation is based on conformance to current residential construction practices (not necessarily the preferred method of installation).

Flat Roof Parapet: an upstand along the edge of a flat roof. An acceptable parapet flashing prevents water from entering the top of the wall, usually requiring a slope and waterproof membrane underlay.

Inverted Soffit: soffits installed horizontal or sloping toward the building, where water on the soffit may drain to the top of the adjacent wall. An acceptable inverted soffit prevents water on top of the soffit cladding draining into the wall.

Roof/Wall Junction: transition between a vertical wall and a sloped or a flat roof at the base of the wall. An acceptable roof/wall junction is flashed with metal, backed with a membrane if the roof is flat, directing moisture inside the wall cladding onto the roof and preventing moisture on the roof from entering into the wall.

Saddle: connection of a solid wall guardrail or roof parapet to a vertical wall. An acceptable saddle is flashed with metal, with an end dam, preventing moisture leakage from the horizontal surface into the wall.

Deck: an exterior living space with a traffic bearing surface, installed over occupied interior living space. An acceptable deck provides a durable, watertight surface, and is free of ponding. The deck base flashing should protect the wall from water on the deck, and provide drainage of moisture within the wall cladding onto the deck surface. The deck edge flashing (if installed in lieu of built-in drains or scuppers) should direct water off the deck and away from wall surfaces below.

Balcony: an exterior flat foot traffic bearing surface installed over exterior space, connected to a floor above grade at the same level. An acceptable balcony requires an effective base wall flashing, and provisions for drainage away from the wall surfaces below.

Patio: similar to a ground floor balcony. An acceptable patio is installed below the adjacent interior floor level, and sloped away from the foundation for drainage.

Exterior Walkway: an exposed area of the building used to provide access to suites above grade. The walkways may be installed over living space, and are typically bound by living space on one side. An acceptable exterior walkway has similar requirements to a deck or balcony.

Exposed Column: a column supporting exterior framing for balconies or walkways, and canopies over entrances, exposed on all sides. An acceptable exposed column is flashed at the base to direct water away from the wall surfaces below, and prevent leakage from the deck or balcony inside the wall, unless it terminates at grade on a foundation isolated from the building.

Horizontal Transition: a transition between claddings, an expansion or control joint, or change in plane of the exterior cladding where the joint or ledge formed is horizontal when viewed in elevation. An acceptable horizontal transition provides drainage of moisture inside the wall or on the wall surface away from the wall surfaces below.

Vertical Transition: a transition between claddings, an expansion or control joint, or change in plane of the exterior cladding which is vertical when viewed in elevation. An acceptable vertical transition provides drainage of moisture from the plane of the weather barrier to the exterior at the base of the wall and at intersections with horizontal transitions.

Door Sill: bottom of door. An acceptable door sill provides drainage of the threshold away from the wall surface below, forming an effective drip edge.

Door Head: top of door. An acceptable door head is flashed to allow moisture behind the wall cladding above the door to drain to the exterior away from the door sill. An acceptable door head flashing is sloped to the exterior, extends approximately 19 mm beyond the jamb framing or has end dams at either end, and keeps run off from the flashing away from the head and jamb details.

Window Sill: bottom of window. An acceptable window sill provides drainage of the sill section away from the wall surfaces below, forming an effective drip edge.

Window Head: top of window. An acceptable window head is flashed to allow moisture behind the cladding above the window to drain to the exterior away from the window sill. An acceptable window head flashing is adequately sloped to the exterior, extends approximately 19 mm beyond the jamb framing or has end dams at either end, and keeps run off from the flashing away from the head and jamb details.

Penetrations

An acceptable design for penetrations requires the installation of a flashing, correctly lapped by the sheathing paper to allow for drainage of moisture behind the cladding, and designed to prevent leakage through the penetration to the interior. An acceptable penetration should be constructed using a durable and waterproof material, and installed based on conformance to current residential construction practices with weather tight joints between the exterior cladding and penetration. Design is considered poor if there is no flashing, and if a non-durable material (such as a plastic dryer vent) cannot be replaced without removal of the cladding.

Definitions for various penetration details are provided below:

Other Vents and Inlets: include gas fireplace, kitchen, bathroom exhaust, and furnace combustion vents.

Electrical Fixtures: include exterior lights and electrical boxes.

Scupper: drainage of a flat roof, deck or balcony through an opening or enclosure which penetrates a wall or solid guard, and drains to the exterior. An acceptable scupper drains away from the wall surface, unless connected to a downspout.

Water, Power, Gas Lines: include all service connections through the wall.

Drainage

Wall exposure to wind driven rains is often affected by the protection and provisions for drainage of the adjacent roof assemblies. The roof overhang, relative to the height of the wall, may protect the wall from wetting. For example, the lower part of a wall four metres high is unprotected by most normal residential roof overhangs above. Some walls may be exposed to additional moisture during rains, caused by run off or splashing from adjacent roof areas. Additional provisions for drainage which may affect the exposure to moisture of the wall are listed on the worksheet.

D. SYMPTOM DESCRIPTION

This worksheet is used to describe the symptoms observed for each moisture problem reported. The worksheet is combined with a *Failure Mechanism* worksheet, to classify the design, construction, maintenance, and operation of the building, and indicate whether they contributed to the problem noted. Each building or wall type may contain more than one performance related problem, requiring a symptom description for each, indicated by two letters specific to the *Building Identification Number*.

The *Problem Orientation* describes on which elevations the problem was experienced. An answer of "NK" indicates that the elevation was not investigated for the problem.

The *Problem Location* indicates the approximate location over the height of the exterior wall where the problem was observed. With many problems, deterioration is often most significant at the floor level as a result of drainage through the wall and eventual ponding at the floor level.

Specific moisture damage to the wall components is documented by the table "*Deterioration Observed at...*". The worst case deterioration observed for each layer observed should be recorded.

The *Percentage Area Of Wall Type Affected* provides a ratio of the wall area affected by the moisture problem, relative to the total area for that wall type (including windows and doors).

The *Problem Categories* provide a list various typical moisture related problems. All problem categories which may have contributed to the problem should be selected, discussed in further detail in the *Description of Problem*.

The *History, Remedial Work Status, Success Of Remedial Work, Percentage Of Total Repair Costs Attributed to this Problem*, and exterior conditions for symptoms are also included, when known.

E. FAILURE MECHANISMS

Three possible sources of moisture are presented; *Exterior Moisture, Interior Moisture and Construction Moisture*. *Exterior Moisture* includes water which entered the wall from the exterior, such as direct rain penetration. *Interior Moisture* includes water that entered the wall from the interior, either as vapour or liquid, such as leakage of an unconnected bathroom exhaust into the wall. *Construction Moisture* includes water that was in the wall during construction and was trapped following completion, such as the use of wet wood for framing. Generally, only one of the three sources of moisture will apply to each problem.

For *Exterior Moisture*, the percent contribution of the sources should add to 100%. Similarly, the path through the exterior cladding (including *Failed Material, At Penetration, and Poor Flashing Details*) and the *Path Through The Exterior Water Barrier*, should each have entries totaling 100%. For example, water leakage experienced through a window perimeter is in most cases caused by exterior moisture due to direct rain penetration. For stucco clad buildings, the path of moisture through the exterior cladding typically includes inherent pores and normal cracks in the cladding, and gaps at window head and sill details.

The confidence column for each moisture source provides a judgement of the percent contribution estimate, rated *Low, Medium or High*. A *High* level of confidence includes conditions observed by the evaluator during dynamic loading. A *Medium* level of confidence includes conditions observed by a competent person with evidence of the problem observed. A *Low* level of confidence provides an estimate of conditions based on reported information or inference without direct evidence observed.

Similar requirements to exterior moisture exist for *Interior Moisture And Construction Moisture*.

The *Cause of the Moisture Problem* is classified, based on design, construction, maintenance and operation of the building. *Not Designed* means the specific details related to the problem were not described in enough detail in the plans and specifications that they could be built by an experienced contractor. An example of poor construction is the installation of a window head flashing back-sloped toward the building. An example of poor maintenance includes failed exterior sealants on a face sealed window frame assembly. *Not Maintainable* typically refers to items which contributed to leakage, however, should not require routine maintenance such as a sheathing paper lap installed behind the cladding. An example of poor operation includes excessive humidification, resulting in condensation on the windows or framing at exterior temperatures warmer than approximately -30 °C. Contributing causes to the moisture problem are indicated in the second column.

In addition, each problem and the causes contributing to it are described in the *Description of Problem* on the *Symptom Description* worksheet.

Evaluated by: _____ **Date:** _____

Data Source: Specific Investigation for this Study _____ Historical Info From Files _____

Constructed for: Market _____ Occupant _____ Subsidized _____ Unknown _____

Year Constructed: _____

Number of Storeys: _____ **Number of Living Units:** _____

Cost of Moisture Related Problem Investigation $ _____ Remedial Repairs $ _____

Shielding: check the appropriate box for each elevation (leave blank if unknown)

	N	S	E	W	Guideline
Minimal					No Obstruction or Local Shielding (i.e. Ridge)
Low					Few Small or Lower Obstructions Within 2 Building Heights
Moderate					Many or Large Obstructions Within 2 Building Heights
High					Large Buildings Immediately Adjacent

Windows

Manufacturer (##)			**Sash Type**	Not Known	
Frame Type	Wood			Other	
	Wood Clad			Awning + Fixed	
	Vinyl			Casement + Fixed	
	Aluminum w/ Thermal Break			All Fixed	
	Other			Slider + Fixed	
	Not Known		**Frame Joints**	Not Known	
Design	Face Sealed			Sealed, Failed	
	Drained			Sealed, Good Condition	
	Rain Screen			Not Sealed	
	Not Known		**Flange**	Not Known	
Sealant at Exterior Perimeter	Yes			No Flange	
	No			Brick Mold	
	Not Known			Flange Under Paper Lap	
Placement	Flush			Flange Over w/ Sealant	
	Rebate			Flange w/ Membrane	
	Not Known			Flange Taped	
				Flange Over Paper	
				Other	

Additional pages of general building notes are included (tick): _____

General Building Information

This information applies to the entire building and is not unique to one wall assembly or performance problem.

Building Identification Number (#): _____ **Page 1 of** _____

Component (when a material is used in more than one layer, show layer numbers, and more than one value in other columns if needed)	Layer No.(s)	Thickness (mm)	Material Quality P A NK	Installation Quality P A NK
Low Permeance Paint or Stain				
High Permeance Paint or Stain				
Horizontal Wood Siding				
Vertical Wood Siding				
Wood Sheet				
Vinyl Siding				
Horizontal Metal Siding				
Metal Panels				
EIFS				
2 Coat Cement Stucco & Lath				
3 Coat Cement Stucco & Lath				
Acrylic Stucco Finish				
Unit Masonry				
Air Space				
Perforated Polyethylene Housewrap				
Polyolefin Housewrap				
Asphalt Impregnated Paper		(Minutes)		
Modified Bituminous Membrane				
Plywood (Untreated)				
Plywood (Treated)				
Waferboard / OSB				
Exterior Grade Gypsum Board				
Fiber Faced Gypsum Board (Dens-Glas)				
Semi-rigid Fiberglass Sheathing				
Foam Sheathing				
Wood Framing (circle thickness)		89 or 140		
Fiberglas Insulation (Yes or No)				
Polyethylene Sheet				
Interior Gypsum Board				
Other (specify)				

Percentage of Building Wall Surface _____ %

Most Airtight Layer _____

Level of Airtightness _____ 1(poor) - 5 (good) or NK

Moisture Barrier Layer _____

Wall Assembly Description

Use one copy for each type of wall on the building.

Building Identification Number: _____ **Page**____ **of** ____ **Wall Type (##)** _____

Wall Details	Detail Exists? Yes No NA NK	Flashed & Drained? Yes No NA NK	Design Quality Poor Acceptable NA NK	Material Quality Poor Acceptable NA NK	Install Quality Poor Acceptable NA NK
Flat Roof Parapet					
Inverted Soffit					
Roof / Wall Junctions					
Saddle (e.g. Guardrail)					
Decks					
Balconies					
Patios					
Exterior Walkways					
Exposed Columns					
Horizontal Transitions					
Vertical Transitions					
Door Sills					
Door Heads					
Window Sills					
Window Heads					
Other					

Notes

Penetrations	Detail Exists? Y N NK NA	Flashed? Y N NA NK	Design Quality P A NA NK	Material Quality P A NA NK	Install Quality P A NA NK
Dryer Vent					
Other Vents & Inlets					
Guardrail Attachment					
Electrical Fixtures					
Scupper					
Water, Power,Gas Lines					
Other					

Eavestroughs & Downspouts	Exist? Yes No NK	Design Quality P A NA NK	Material Quality P A NA NK	Install Quality P A NA NK

Roof Overhang Width (mm): _____ **Height of Wall (mm):** _____ **Top of Wall to u/s Soffit (mm):** _____

Other Drainage Provisions: None _____ Balcony Scuppers _____ Sloped Eaves w/o Eavestrough ____
(tick all that apply)
Roof Scuppers _____ Deck / Walkway Scuppers ____ Downspouts _____ Other _____

Building Identification Number: _____ **Page** _____ **of** _____ **Wall Type:** _____

Problem Number (LL): _____

% Area of Wall Type Affected: _____

Problem Orientation	Y	N	NK	NA
North				
East				
South				
West				

Problem Location (enter "NK" "Y" or "NA" for each)

Floor	Rim Joist / Floor Slab	Wall Section
Basement		
1		
2		
3		
4		
Parapet		

Problem Catagories (tick all that apply)

	Window: Poor seal at frame to cladding joints
	Window: Poor seal at corner mitre joints
	Window or door: Poor head flashing
	Window: Poor sill flashing
	Door: Poor sill flashing
	Window: Poor weather barrier installation
	Window: Leakage
	Poor deck or balcony waterproofing - field
	Poor deck or balcony waterproofing - wall
	Poor deck or balcony waterproofing - at outer edge
	Poor Parapet/Guardrail cap flashings
	Poor Base/Transition/Control Joint flashings
	Poor Roof/Wall Joint flashings
	Poor drainage (eavestrough, scuppers, etc.)
	Poor vent: interior moisture
	Poor vent: exterior moisture
	Penetration: poor seal
	Poor Other Details
	Material / Installation Defects - Wall Section

Deterioration Observed at:

Layer No.	Side of Layer A=Inside B=Outside C=Both	Symptoms A=Stains B=Saturated, no rot C=Mold or Mildew D=Decay or Rot E=Dimensional Change F=Cracking G=Other	Severity A=Minor B=Moderate C=Severe

History: problem occurred _____ years after completion

problem first noticed _____ years after completion

Remedial Work Status:

None ____ Partly Complete ____ Complete ____ Not Known ____

Success of Remedial Work:

Successful _____ Unsuccessful* _____ Not Known _____

* describe why in description of problem

% of Total Repair Cost Attributed to this Problem _____

Symptoms appear with (tick all that apply): **Rain alone** ____ **Wind & rain** ____ **Wet snow** ____ **Thaw after cold period** ____

Description of Problem (Describe symptoms, probable cause(s), append pages if needed and a photograph if possible):

_____

_____ (tick if continued): ____

Symptom Description

Use one copy for each symptom observed for each type of wall. Problems are numbered by building.

Building Identification Number: _____ **Page** _____ **of** _____ **Wall Type:** _____ **Problem Number:** _____

Exterior Moisture Tick if NA ___ NK ___	% Contribution	Confidence Lo Med Hi
Source		
Direct Rain Penetration		
Run-off		
Splash Back		
Ponding Water		
Snow Melt		
Indirect (through window)		
Other _____		
Failed Material		
Sealant / Caulking		
Cladding		
Normal pores and cracks		
Other _____		
At Penetration		
Vent Hood (Dryer, etc.)		
Guardrail Attachment		
Electrical Fixtures		
Scupper		
Water, Power, Gas Lines		
Other _____		
Poor Flashing Details		
Flat Roof Parapet		
Roof / Wall Connection		
Saddle (Guardrail, etc.)		
Deck Exterior Edge		
Deck Base Flashing		
Material Transition		
Window / Door Sill		
Window / Door Head		
Inherent Pores or Joints		
Other		
Path Through Exterior Water Barrier		
No Exterior Water Barrier		
Discontinuities		

Exterior Moisture, cont.	% Contribution	Confidence Lo Med Hi
Material Degradation		
No or Reversed Lap		
At Flashing		
At Penetration		
Other _____		
Interior Moisture Tick if NA _____ NK _____		
None Identified		
Wet Basement		
Open Sump		
Interior Clothes Drying		
Abnormal Occupancy		
Vents leaking into wall		
Elevated humidification		
Normal humidification		
Other _____		
Wall Condensing Surface (Layer No.)		
Primary: _____		
Secondary: _____		
Window Condensation (tick as applicable)		
On Glass		
On Frames		
Construction Moisture Tick if NA _____ NK _____		
Wet Materials Used		
Exposure to Weather		
Installation Uses Water		
Other _____		
Cause of Moisture Problem (tick contributing causes in box 2)		
Design: Acceptable Poor Not designed		
Construction: Acceptable Poor		
Maintenance: Acceptable Poor Not Maintainable		
Operation: Acceptable Poor		

Failure Mechanism

Use one copy for each problem on the building.

Building Identification Number: _____ **Page** _____ **of** _____ **Wall Type:** _____ **Problem Number (LL):** _____

Problem & Symptom Description

Use one copy for each symptom observed for each type of wall. Problems are numbered by building.

Building Identification Number: _____ **Page** ____ **of** ____ **Problem No.**_____ **Wall Type:** _____

General Building Notes

Describe aspects of building which are not included in descriptions of problems, including notes of why particular details are rated poor.

Building Identification Number (#): _____ Page _____ of _____